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FOURTH ANNUAL REPORT
ADVANCED MAIL SYSTEMS SCANNER TECHNOLOGY

Executive Summary and Appendixes A-D

October 1978

Prepared by
NOSC Sensor Processing and Analysis Division (Code 732)
NAVAL OCEAN SYSTEMS CENTER
San Diego, California 92152

FOR
US POSTAL SERVICE
OFFICE OF ADVANCED MAIL SYSTEMS DEVELOPMENT

Approved for public release; distribution unlimited

AMSD

of Code 8246, and Robert W Basinger, System Development Corporation, contractor. This report is a compilation of data presented by all team members and was approved for publication in October 1978.

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The objective of the effort described herein is to provide technical consultation, equipment, and support services to the US Postal Service which will contribute to the development of the system definition of a new-concept processing system, the Electronic Message Service (EMS). Included in the scope of effort are investigations of high-speed image scanning technology, image frame memory storage, image enhancement, and the fabrication of a scanner/frame-store memory test assembly. The fourth annual report briefly describes the individual

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efforts of the reporting period in an executive summary and provides in-depth data in four appendixes: ~~Appendix A,~~ Advanced Illumination Correction; ~~Appendix B,~~ Document Data Base; ~~Appendix C,~~ Paper Reflectance as a Function of Data Density as Seen by a High-Resolution Reflectometer; and ~~Appendix D,~~ Image Capture and Analysis System – System Operator's Manual.

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OBJECTIVES

1. Provide the US Postal Service the technical consultation, equipment, and support services which will contribute to the development of the system definition of a new-concept processing system, the Electronic Message Service (EMS). Include in this scope of effort (1) investigations in scanner technology, image frame memory storage, and image enhancement, and (2) the design and fabrication of a scanner/frame-store memory test assembly.

2. Contribute to the selection of the most optimum imaging devices and techniques for high-speed image acquisition. Provide reliable designs of high-speed image processing logic which will preserve the quality of the image while reducing the image storage and transmission requirements and minimizing vulnerability of the image information to noise during processing, transmission, and reproduction.

3. Act as technical consultants to the USPS Office of Advanced Mail Systems Development in preparing technical requirements and statements of work and evaluating technical proposals and contractor performance; and perform technical evaluation of contractor-produced developmental equipment.

RESULTS

The principal program goals during this reporting period were threefold.

1. The first was to define and begin investigations on a document data base containing categories of documented images which customers on the USPS may wish to transmit. Data base categories were selected and initial, promising investigations were completed and are reported here.

2. The second goal was to accelerate the completion of the ICAS equipment upgrade so that not only could the data base test run-times be reduced, but the system will be ready to interface with the high-speed Fairchild scanner due in April 1979. At the time of this report, it appears that the ICAS will be completely ready to accept full-capacity (20.8896 megabit), full-speed (233.5 megabit per second) data from the Fairchild 10-document-per-second scanner.

3. The third goal was to provide continuing support to the USPS in all areas of image acquisition, processing, storage, enhancement, compression, and display. The tasks accomplished to provide this support are described in the executive summary and appendixes which follow.

FUTURE NOSC PLANS

1. Expand and continue data base acquisition and analysis.
2. Complete 25-megabit memory, color recorder, and color display interface.
3. Consummate contract(s) on time delay and integration (TDI) imagers.
4. Evaluate Fairchild EDM scanner.
5. Evaluate performance of high-speed imaging devices and the Image Capture and Analysis System (ICAS) at highest possible scan speeds.
6. Capture and analyze full color images.
7. Apply advanced techniques to improve image quality, classification accuracy, and compressibility.

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GLOSSARY

GLOSSARY

ac	Alternating current
A/D	Analog to digital
address	Peripheral device selection or memory location specification
ALU	Arithmetic/logic unit
AMSD	Office of Advanced Mail Systems Development
ASCII	American Standard Code for Information Interchange
baud	Effective bit rate in bits per second
bit	The smallest piece of digital information – either 0 or 1
bit serial	The bits of a character are transmitted serially
bootstrap	A built-in function which eases system start-up
byte	A logical group of bits (8 is standard)
CCD	Charge-coupled device
CCPD	Charge-coupled photodiode
CPE	Central processing element
CPU	Central processing unit
CTF	Contrast transfer function
D/A	Digital to analog
dc	Direct current
DIA	Digital Image Analyzer
DIP	Dual In-line Package
DMA	Direct memory access
DPCM	Differential pulse code modulation
EAROM	Electrically alterable read-only memory
ECL	Emitter-coupled logic
EDM	Engineering development model
EMSS	Electronic Message Service System
FCU	Format Control Unit
FDS	First-difference statistics
FET	Field effect transistor
Fetch	Microroutine which retrieves MCU instructions from program memory
file	On magnetic tape, a grouping of logical records
filemark	A logical gap between tape files
firmware	System control by use of ROMs and a microprogram sequencer
fpf bit	Front-panel fetch bit; indicates that MCU instruction is from front panel
FSM	Frame-Store Memory
GFE	Government furnished equipment
GOMAC	Government Microcircuits Applications Conference

GPIB	IEEE STD 488-1975 General-Purpose Interface Bus for asynchronous data communications
Gray code	A binary code in which only one bit changes at each increment
HCU	Hard-copy unit
HIC	Hardware Illumination Corrector
Hz	Hertz; cycles per second
ICAS	Image Capture and Analysis System
IEEE	Institute of Electrical and Electronics Engineers
interrecord gap	Physical space between magnetic tape logical records
I/O	Input/output
k	1024
kW	Kilowatts
LDTB	Large Drum Test Bed
LED	Light-emitting diode
LFPM	Linear feet per minute
LIES	Laboratory Image Exploitation System
listener	A device which may receive data on the GPIB
logical record	A logical grouping of data on magnetic tape. In an image, a video line is treated as a logical record
LSI	Large-scale integration
M	Mega-; million
machine language	Operation instructions interpretable by the machine being operated
macroinstruction	A machine language instruction which initiates a sequence of basic machine operations
macrolevel	A level at which an operator may directly communicate with a machine; ie, machine language level
macroprogram	A logical sequence of macroinstructions
MARB	Memory Address Register Bus
MCU	Memory Control Unit
message	On the GPIB, a sequence of data and/or control operations transmitted
MIC	Memory Interface Card
MICC	Memory Interface Control Card
microaddress	Micromemory address
microcode	Bit-by-bit implementation of microinstructions
microcontrol	Control of individual hardware resources by use of a micro-program structure
microinstruction	A basic machine operation instruction containing control for all hardware resources (eg, data paths, registers, ALUs)
microlevel	Hardware direct-control level
micromemory	Memory (usually ROM) which contains microinstructions
micromemory address	Specification of location within a micromemory

microprogram	A logical sequence of microinstructions
microroutine	A microprogram or part thereof
MIU	Memory Interface Unit
MOS	Metal oxide semiconductor
MSB	Most significant bit
MTBF	Mean time between failures
MTF	Modulation transfer function
n	Multiplex ratio
NELC	Naval Electronics Laboratory Center
nm	Nanometre
NOSC	Naval Ocean Systems Center
ns	Nanosecond
NTC	National Telecommunications Conference
OCR	Optical Character Recognition
page	An 8½-by-11-inch acquired image or original copy
PBS	Pel brightness statistics
PC	Personality chassis
PCR	Print contrast ratio = $(r_{max} - r_{min})/r_{max}$
pel	Picture element
pixel	Picture element
PPHE	Printer and paper-handling equipment
PPHE/IU	Printer and paper-handling equipment/input unit
PPE	Printer/plotter equipment
program	Sequence of machine instructions
PROM	Programmable read-only memory
r	Reflectivity
RAC	Relative address coding
RALU	Register arithmetic logic unit
RAM	Random-access (read/write) memory
record	Logical record
RLC	Run length coding
RLS	Run length statistics
ROM	Read-only memory
s	Second
SDC	System Development Corporation
SDTB	Small Drum Test Bed
SFI	Spatial Frequency Identification
SID	Silicon imaging device
SPADE	Storage, Processing, and Display Equipment
SPIE	Society of Photo-Optical Instrumentation Engineers
t_{mac}	Memory access time
t_{mcy}	Memory cycle time
talker	A device which may transmit asynchronous data on the GPIB

TDI	Time delay and integration
TDMA	Time-division multiple access
three-wire handshake	The Hewlett-Packard patented method of guaranteeing asynchronous communication capability on the GPIB
TTL	Transistor-transistor logic
UDK	User Definable Key
USPS	United States Postal Service
UV	Ultraviolet
VTS	Video transmission system (Navy)
word	A grouping of 1 or more bytes (in the MCU, a word contains 6 bytes, or 48 bits)

RELEVANCE TO DOD MISSION

RELEVANCE TO DoD MISSION

The concept definition phase of the Electronic Message Service System (EMSS) is nearing completion, and selected alternatives will soon be forthcoming, which the USPS will evaluate to select a proposed system approach. If instrumented, it will become the second largest communication and information exchange system in the US. Participation on the imaging interface aspects of the system provides intimate familiarity for the Navy, which will be able to assist in utilization of the network for military purposes in a time of national need.

The actual imaging investigation is relevant to recent and current NOSC programs involving facsimile and submarine sensors. One of the requirements of the Tactical Flag Command Center program is image transmission. Other requirements for image acquisition, processing, storage, and transmission are implicated in work for the Naval Intelligence Support Center. The USPS Image Capture and Analysis System (ICAS) has been designed to interchange data with the NOSC video test bed in the Display Equipment Development Branch, Code 8247. Digital image tapes can be generated by scanning or by converting tapes from other sources to a format compatible with the Laser Recording System located in the Marine Corps and Special Systems Branch, Code 8125.

One of the program procurements is a large, high-speed imaging, charge-coupled device (CCD) which can operate in the time delay and integration (TDI) mode. This single device is capable of acquiring full-page data at a rate of 20 pages per second. The high performance of the device makes it applicable for telereconnaissance, teleguidance, battlefield surveillance, and intrusion detection as well as document imaging. Successful operation of the device has been witnessed at the contractor's facility, and negotiations are being considered for refinement and advancement of this important work.

The experience gained with microprocessor architecture, image processing, high-speed storage and retrieval, display, and hard-copy generation is also valuable to the Navy. Very little of the work within the DoD and academic communities involves high-speed, real-time hardware and algorithm developments which will support military applications such as:

- ocean surveillance
- telereconnaissance
- teleguidance
- battlefield surveillance
- intrusion detection
- image transmission systems
- pattern/character recognition
- word processing

EXECUTIVE SUMMARY

INTRODUCTION

The overall activities within the total Scanner Technology program are intended to identify the problems associated with scanning highly variable hard-copy documents at very high speed and defining solutions or approaches to solutions to these problems. The major problems are associated with variation in data structure (ie, typewritten or handwritten text to continuous-tone pictorials), full color or black and white, contrasts that vary to as low as 30% differential between data and substrate, and variation in resolution needs. Some of the more significant problem areas investigated to date include illumination requirements, thresholding or data decision logic, enhancement, prescanning, and the effects of advanced technology.

This report is the fourth in a series of annual summary reports and covers work during the period of October 1977 through September 1978. During this period the primary hardware effort was directed toward system improvement with the addition of multiport input capability, progress toward full 25-megabit memory, and more expedient processing. Considerable effort was applied to software support. Acquisition routines, analysis programs, and operational capability in general were improved.

The following sections of this executive summary contain brief summations of the individually identifiable efforts. Further detail is available in the appendixes to this report. Parenthetical alphabetics in the paragraph headings refer to the appendixes which provide additional in-depth data. A short history concludes the executive summary.

1978 TASKS

For the year ending 9 October 1978 the services performed can be divided into four categories. The categories and the tasks within each are described in the following paragraphs.

HARDWARE DELIVERABLES

FOUR A/D CONVERTERS ADDED TO ICAS

To accommodate the receipt of image data from imaging devices having four data ports, it was necessary to integrate four A/D converters into the ICAS. The converters were acquired, tested, and mounted in the ICAS system during this year's program. The converters provide 60-megapel-per-second capability on three input channels and 100-megapel-per-second capability on the fourth input channel. Analog data are converted to 6-bit binary form, providing a range of 64 possible brightness levels for each pel.

GAIN/LEVEL CONTROL ADDED TO A/D CONVERTER CHASSIS

Remotely controllable gain and level circuits were added to the A/D Converter Chassis in order to provide control of dynamic range and threshold level of incoming analog signals before digitization. The circuits can be controlled remotely from the memory control unit via the IEEE-488 interface bus. The bandwidth of these 20-dB amplifiers is approximately 30 MHz.

CALIBRATION MONITORS ADDED TO A/D CONVERTER CHASSIS

Calibration monitors added during the reporting period obviate the connection of a very expensive logic analyzer instrument to the A/D converter outputs during the setup of image illumination parameters. Light emitting diodes (LEDs) are available on the front panels of both A/D converter chassis so that an operator can detect the maximum and minimum response of the system input without special external instrumentation.

PERSONALITY CHASSIS (PC) COMPLETED

The Personality Chassis was completed during this reporting period. Personality modules have been designed and installed which allow the single-ported Fairchild CCD 121H data to be acquired. Modules were also developed to provide an input capability for the RCA imaging device. This RCA Time Delay and Integration (TDI) imager operates in two possible modes. In one mode data can be obtained in four bit streams which contain data from each of the four adjacent pels. In the other mode, two pairs of bit streams are available from each end of the imaging device which provide concurrent analog brightness signals from two spatially totally isolated image areas from the document. Both of these operating modes of the imager can be accommodated by the personality modules and the personality chassis. The latter mode is applicable to the USPS/Fairchild bilevel scanner and will be used to interface this scanner to ICAS during the coming year.

MEMORY INTERFACE UNIT (MIU) BASEPLANE COMPLETED

Because of the expansion of memory capacity it was necessary to develop and install an MIU in order to distribute the 48-bit data words to one or all of the eight memory modules. The MIU has been designed and the baseplane wiring is complete. A modification to the MIU is discussed in the future plans section, because of some redesign required to improve the noise immunity of the signal paths.

MEMORY INTERFACE CONTROL CARDS (MICCs) COMPLETED

The two MICCs have been designed and operate successfully within the MIU. One or both of these will be modified to provide new pin outs for improvement of noise immunity. This is discussed in the future plans section.

MEMORY INTERFACE CARDS (MICs) COMPLETED

Wire-wrap MICs were completed during the performance period, followed by the layout of printed circuit MIC cards. Eight such cards are now in operation in the MIU.

MEMORY CONTROL UNIT (MCU) MODIFIED FOR 25-MEGABIT ADDRESS

The MCU was designed to accommodate 64k words of 48 bits each. The addition of the seven new memory modules required the address to expand by a factor of eight. This resulted in the requirement for a three-wire addition to the address bus. It also entailed some minor changes in the configuration of an instruction word in order to provide the address field (19 bits) required to designate a specific address in the 25-megabit memory.

NEW IMAGER DRIVER MODULES DESIGNED/INSTALLED FOR 121H IMAGER

The Fairchild type 121H imager requires different driving signals than its predecessor, the old model 121. It also provides a higher output level. Thus, the video amplifier for the image signal also required modification to operate with the new higher-performance device.

HARDWARE DISPLAY MODULE DESIGNED/INSTALLED FOR MIU

A new hardware display module was designed and fabricated for use with the MIU. This module offers the advantage of accepting data from any of the memory modules and formatting the information for transmission to the display digital-to-analog (D/A) converter. This device divides a 48-bit word into its eight respective 6-bit pel brightness words and transmits them sequentially to the display for presentation on the cathode ray tube (CRT).

JOYSTICK CONTROL OF DISPLAYED IMAGE COORDINATES PROVIDED

A joystick has been added to the operator station of the Tektronix 4051 terminal. It provides for operator selection of a desired subsection of the main 8½-by-11-inch image which has been captured. The dimensions of the entire image are 1700 pels by 2200 pels. The display CRT of the ICAS only presents an image area of 496 (wide) by 482 (high) elements. The joystick feature allows the operator to manipulate the coordinates of the starting address for the displayed subsection and in essence allows scrolling in both the X and Y dimensions over the entire image area.

SOFTWARE SUPPORT DELIVERABLES

RESOLUTION TEST OF NIKON VS CANON LENSES

The ICAS now uses the Nikon 55-mm Micro Nikkor lens in the Large Drum Test Bed (LDTB). The purpose of this test was to evaluate the relative resolution performance of this lens and the Canon 85-mm f1.2 SSC Aspherical lens used in the Fairchild scanner system. (See Support Activities.) Special software was prepared to provide analysis of the smaller format image (8½ by 8½ inches). The software will now support any programmed image format.

IMPROVED RESOLUTION TEST CALCULATION

In the setup procedure for the LDTB it is necessary to determine the relative positions of the imager and lens with respect to the target document. The improved software provides decimal values for both horizontal and vertical resolution of the scan density.

ILLUMINATION CORRECTION STUDY ROUTINES

The entire process of illumination correction was studied during the past year. Most of the data concerning this study are contained in appendix A. Considerable software support was required in order to investigate new strategies for accomplishing the process of illumination correction without decreasing the apparent signal-to-noise ratio.

SYSTEM NOISE/SPURIOUS SIGNAL ANALYSIS TEST ROUTINE

In the study of illumination correction performance, a number of important observations were made concerning the small signal variations before and after illumination correction which would seriously constrain the use of run length type compression algorithms on the data for transmission. One of these was the odd/even pel brightness response difference which is discussed in appendix A. System noise also stems from the high-resolution scanning of ordinary bond paper which contains small-amplitude but high-spatial-frequency variations in reflection density. These two sources of variation contribute greatly to the reduction in compressibility of an image and detract from the cosmetic appearance to some extent, particularly when viewing soft-copy images. This noise analysis test routine was instrumental in localizing the sources of these two detrimental contributors to the image acquisition and data compression processes.

IMPROVED WHITE STANDARD ACQUISITION ROUTINE

Studies of the consequences of illumination correction showed that although illumination correction provided an excellent first-order improvement in the uniformity of response of the captured document, it also increased the noise levels of the less significant bit planes. Study routines were written to provide a number of strategies by which the process of white standard acquisition and subsequent illumination correction was performed.

PROGRAMMABLE NOISE FILTER ALGORITHM

In examining the detailed data obtained during illumination correction studies and system noise performance evaluation, it was noticed that there was a high incidence of sequences in which the value of succeeding picture element brightness varied by only one of the 64 brightness levels. In a large majority of these cases the brightness level would increment by one and return to its original level on the second succeeding pel. Such minor excursions of the data, which could be attributed to odd/even effects (a characteristic of the imaging device itself which is explained in appendix A), greatly reduce the compressibility of the acquired image. The programmable noise filter algorithm provides the capability to smooth this otherwise small-signal, high-frequency variation from the acquired image data, thus greatly improving the compressibility of the image data.

SPATIAL FREQUENCY IDENTIFICATION PROGRAMS (B)

One of the most promising methods for classification of documents by major category (such as typed page and continuous-tone image) is the use of spatial frequency identification. It was postulated that typed pages would have quite regular row and column features which would be identifiable by providing sums of brightness levels in the vertical and horizontal page dimensions. Software was formulated for this data acquisition, and a number of samples of the results of this test are included in appendix B of this report.

IMPROVED IMAGE ANALYSIS PROGRAM

The present program for the acquisition of image data for data base characterization includes Pel Brightness Statistics (PBS), First-Difference Statistics (FDS), horizontal Spatial Frequency Identification (SFI_H), and vertical Spatial Frequency Identification (SFI_V). In view

of the fact that it is contemplated that up to a thousand pages may be acquired for the data base, it is important that the program for analysis and preparation of statistics including the generation of hard copies be minimized to the greatest extent possible. The software for this function has been streamlined to provide higher throughput and better output format. The new program will accommodate data from either tape or the solid-state memory and has the ability to perform the analysis on selected portions of an image area.

IMPROVED MEANDER ANALYSIS PROGRAM

Meander analysis is a generalized form of run length analysis which may include pels from more than one line in a single run. When executed in software, this procedure is time consuming. A previous meander analysis program was modified to utilize the increased size of fast-access storage and realize a savings in execution time of about 30%.

IMPROVED COMPRESSION RATIO CALCULATION

At the end of the generation of statistics related to the various run lengths during a compressibility analysis, it is desirable to perform the compression ratio calculation and present the resulting statistics in meaningful and concise form. This modification to the software greatly improved both the calculations and the presentation of results.

BRIGHTNESS TRANSFER FUNCTION TABLE ROUTINE

A software routine was written to enable an operator to define a nonlinear brightness transfer function which could be applied to stored image data. This transfer function can be used to emphasize or attenuate various features of an image. For example, it is possible to provide a very insensitive response region at the approximate brightness range of the document substrate. Such an unresponsive zone tends to mask blemishes within the paper, artifacts, or pencil notes on otherwise cosmetically acceptable image documents.

REAL-TIME KEYBOARD/JOYSTICK CONTROL OF DISPLAY HARDWARE

Associated with the electrical and mechanical interface of the joystick accessory, there was a requirement for software interaction with the joystick output to modify the address structure for the displayed image. The software was modified to provide this feature.

IMPROVED STATISTICS MANIPULATION ROUTINE

This improvement consists of upgrading the software to allow more useful operator interaction and also provide better display of the resulting statistics.

SELECTIVE THRESHOLD VERSATEC PRINTING

A software routine was written to provide a selectable threshold level for operating upon a stored image to produce a single bilevel (black/white) image which could be presented to the Versatec printer for the generation of a hard-copy output. The operator has the prerogative of selecting any one of the 63 levels to define the threshold between the black and white levels.

DATA BASE IMAGE/STATISTICS CATALOG

Because of the size of the forthcoming data base, software was needed in order to organize files, records, and tapes and for the storage of image and statistical data for easy retrieval and characterization after acquisition. The data base has been set up to accommodate expansion of a number of documents in each of the 21 or more categories which we expect to characterize.

NUMEROUS ICAS DIAGNOSTIC ROUTINES

The ICAS system is going through a significant upgrading of hardware capability. For this reason, as new entities are interfaced with the current equipment, a series of diagnostic routines is usually necessary in order to absolutely confirm that the equipment is operating as intended with the parent equipment. We also occasionally experience failures (mostly in the memory modules) which cause errors in the cosmetic appearance of an image or result in the failure of the software to perform its function. These quickly written diagnostic routines save many man-hours in localizing the faults.

EROS IMAGE DATA REFORMATTING ROUTINE

A request was received from another department within NOSC to extract a portion of an image from a tape for future analysis. A software program was written to accommodate this task. The image has been stored for further operation by the requesting department.

DOCUMENTATION PREPARED

THIRD ANNUAL FORMAL REPORT

For the third year a formal annual report was prepared, covering the progress of the program during fiscal year 1977. This 292-page document was approved by USPS and NOSC for public release. Copies were mailed to approximately 40 interested government agencies and industries in the United States, Canada, and England.

ADVANCED ILLUMINATION CORRECTION REPORT (A)

An advanced illumination correction report was generated to describe studies undertaken during fiscal year 1978 on the subject of illumination correction and system noise. It is contained in this report as appendix A.

DOCUMENT DATA BASE INITIATED

One of the most important events of this reporting period was the formulation of a data base hierarchy and classification system for the USPS imaging study. The data base has been divided into 21 categories and efforts are underway to accumulate at least 10 typical image documents in each of them. Seventy-seven documents in 13 categories have been accumulated, and digitized images of them have been stored on tapes. A subset of 20 such documents has been analyzed for pel brightness statistics and horizontal and vertical spatial frequency characteristics.

NOSC responded to this request with a list of test equipment adequate to support the USPS program activities at NOSC without the use of NOSC test equipment. USPS accepted the recommendation and procured the test equipment, which is now at NOSC.

PROPOSAL EVALUATION

During the reporting period the USPS requested engineering assistance, at Rockville headquarters, for the evaluation of proposals received on the Laboratory Image Exploitation System. This support service was furnished by NOSC.

FAIRCHILD DESIGN REVIEW TECHNICAL ASSISTANCE

During the reporting period Fairchild was completing the fabrication and test of the USPS scanner equipment at Syosset, NY. The NOSC engineering team participated in a number of design reviews and performance evaluation and acceptance test demonstrations throughout the year.

SHORT HISTORY

In October 1974 the USPS and NOSC (then NELC) entered an agreement in which NELC, primarily the Display Division (Code 3100), agreed to provide technical support for one year for the development of scanning technology for the very advanced EMS system. Because of mutual coincidence of goals in image acquisition, processing, storage display, and compression, the USPS and NOSC have continued with interagency agreements to the present.

During the first year ending October 1975 a survey and characterization of imaging devices, off-the-shelf lenses, and available illumination sources was completed. A small drum test bed (SDTD) was designed and fabricated.

A transistor-transistor-logic (TTL) 48-bit minicomputer using Intel 3000 series two-bit-slice devices was designed and fabricated. This was given the name Memory Control Unit (MCU) because its principal function was formatting and interfacing data between a GFE tape deck, a Tektronix terminal, a 65 536-word (48-bit words) memory unit (MU), and the input scanners under test.

A 24-bit emitter-coupled-logic (ECL) equipment was also designed and fabricated. This unit contains 64 each 24-bit words of ECL random-access memory (RAM) and an ECL adder for A plus B (or memory contents) sums. The general purpose format of the unit has not yet been exploited, since it was used initially for the accumulation of pel brightness statistics (PBS) histograms at a 21-megapel-per-second rate. Some simple experiments in edge enhancement and nonlinear video amplitude partitioning were completed during this first-year period.

During the second year ending October 1976 a large drum test bed (LDTB) was fabricated. The new drum has a circumference of 40.96 inches, which is compatible with the 8192-count shaft encoder and dimensionally identical to the USPS paper-handling equipment designed by Pitney Bowes. The illumination source for the new test bed uses Sylvania slit-aperture fluorescent lamps rather than the 1500-W quartz iodide incandescent source. The lamps were procured with phosphors having special spectral emissions which compensated for the low responsivity of the CCD in the blue region. Test and evaluation of candidate imagers was continued. By the end of the 1976 program the following imaging devices

had been evaluated: Reticon RL-512B, Fairchild CCD-100 and CCD-121, RCA SID 51232, and GE 244X188 SID. A software program was written for the MCU which provided a first-order illumination correction procedure for the digitized scanner video. Second-generation CCD driver boards were designed and installed. The ECL microprocessor capability was expanded not only to include PBS but to add first-difference statistics (FDS) and run length statistics (RLS). The equipment now has the nomenclature of Digital Image Analyzer (DIA). Numerous runs of statistics were made and the results included in the annual report.

During this year a contract was awarded to RCA Princeton Laboratories for the design of a prototype time delay and integration (TDI) imager.

The year ending October 1977 encompassed considerable activity in upgrading the ICAS. Planning was initiated for an increase in memory capacity from one memory module of 64k words by 48 bits to a total of eight such modules. This capacity is sufficient to contain a digitized version of a full 1700-by-2200-pel (8½-by-11-inch) document page quantized at 6 bits per pel. The seven additional memory modules were ordered and the design of new electronic circuitry was started. This equipment is the Memory Interface Unit (MIU), which controls access to/from memory and its high-speed users such as the display, the MCU, and the Personality Chassis. The PC was developed also during this time frame. Its function is to accept data from scanner systems at high speed in a wide variety of formats, pack the 6-bit pel data into 48-bit words, and formulate sequential (and special) address locations for storage of the digitized video data streams. The maximum accommodated speed planned to date is four parallel ports, each providing 6-bit digitized pel data at a 21-megapel-per-second data rate (504 megabits per second total).

Remotely controllable gain and level circuits were added to the four channels of ICAS input. These are controllable through an IEEE-488 interface bus.

The GFE Bright tape transport was replaced with two Kennedy tape transports. A Versatec 1200A printer/plotter was added to the ICAS for hard copy. The GFE Tektronix 4023 terminal was replaced by a model 4051 version.

The system software was greatly improved during this period. Programs were developed to generate meander compression analysis routines, digital adaptive threshold verifications of the Fairchild analog equivalent algorithm, and numerous tape format conversions affording compatibility with the Image Processing Institute at USC and terminals at RCA Camden.

APPENDIX A:

ADVANCED ILLUMINATION CORRECTION

by

TR Little
Code 7323
Naval Ocean Systems Center

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APPENDIX A: ADVANCED ILLUMINATION CORRECTION

Background — Sources of Nonuniformity

Several sources of nonuniformity of response are inherent in the conventional image acquisition process. Three are considered in this report.

1. The geometry of the optical scanning system generates an illumination error proportional to the fourth power of the lens acceptance angle θ. (See fig A1 and refer to First Annual Report Advanced Mail Systems Scanner Technology, NELC TR 1965, 22 October 1975.) The effects of the cosine-fourth error can be calculated and plotted as shown in curve A of figure A2.

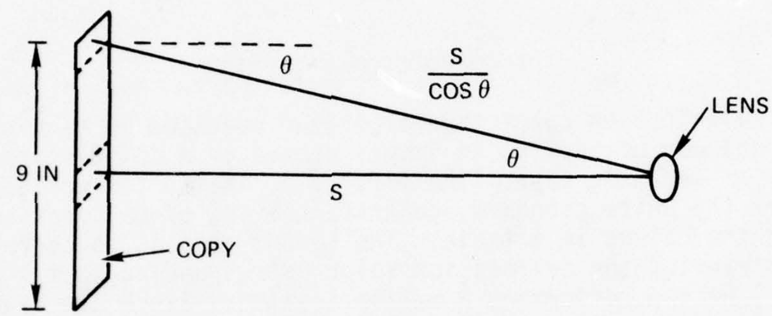


Figure A1. Cosine-fourth geometry.

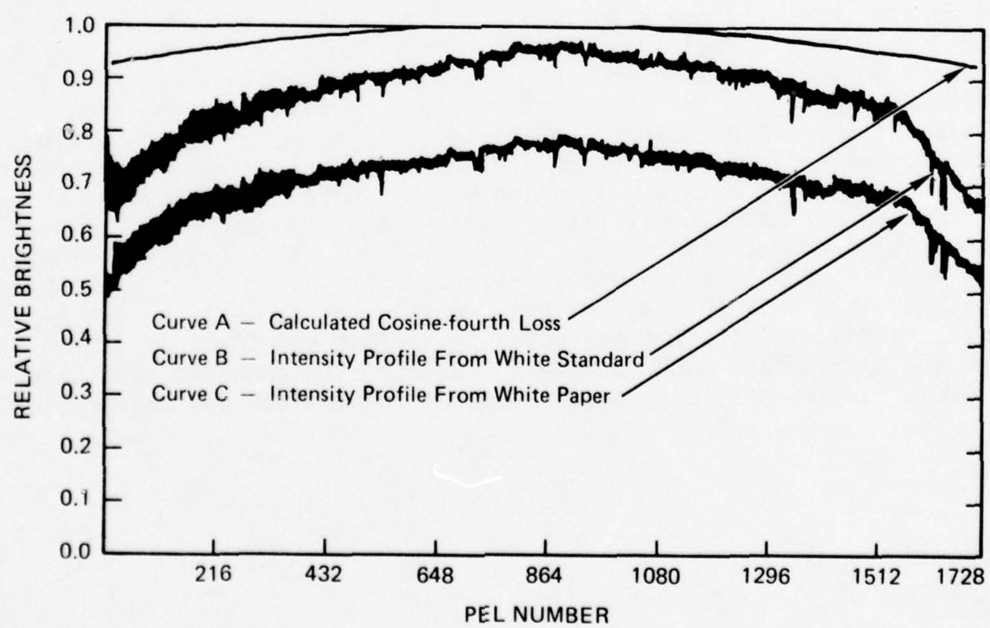


Figure A2. Intensity profile.

The cosine-fourth error causes a loss of illumination level proportional to the distance from the center of the optical axis.

2. There are differences in sensitivity of imager photosites and CCD charge transport inefficiencies. The fine structure in curves B and C of figure A2 is attributed to this class of nonuniformity plus noise.

3. An additional droop in illumination intensity is caused by the light source itself.

An illumination correction algorithm has been developed which attempts to correct all these adverse effects and produce a more faithful reproduction of the original document. A calibration measurement is made of the total system transfer function by use of the most uniform white material available. The algorithm uses this measurement to effect the best possible correction of image data.

The Correction Algorithm

The illumination correction algorithm operates in machine-level software and can be applied to images stored in a solid-state frame-store memory or on magnetic tape. The first step in the correction process is to capture the white standard, generate the set of calibration values, and store the values in a table. The second step is to correct each image pel by extracting the calibration value corresponding to its position on the scan line and performing a multiplication. Since the algorithm is intended to operate in hardware at real-time video rates, a table lookup is substituted for the calculations.

Figure A3 describes the correction algorithm schematically as simulated on the Image-Capture & Analysis System (ICAS) developed at NOSC for the USPS. (Refer to Real Time Digital Correction of Acquisition Errors Applied to Solid State Scanners, by TR Little, Proceedings of the SPIE, vol 119, 25, 26 August 1977.) First, table I is filled in the process of capturing the white standard and table II is computed or loaded into memory from magnetic tape. During a correction, a line position index counter runs in sync with the incoming video. A calibration value is read from table I at each pel time, concatenated with the video sample and used as an address for access to table II. In the ICAS, each 48-bit memory word is used to store eight corrected pel values. The upper bits of the address (variable; ie, the bit precision of table I) select a memory word containing eight corrected pel values and the lower three bits select the appropriate mask. Table II contains the complete multiplication table for all possible combinations of input video and calibration value.

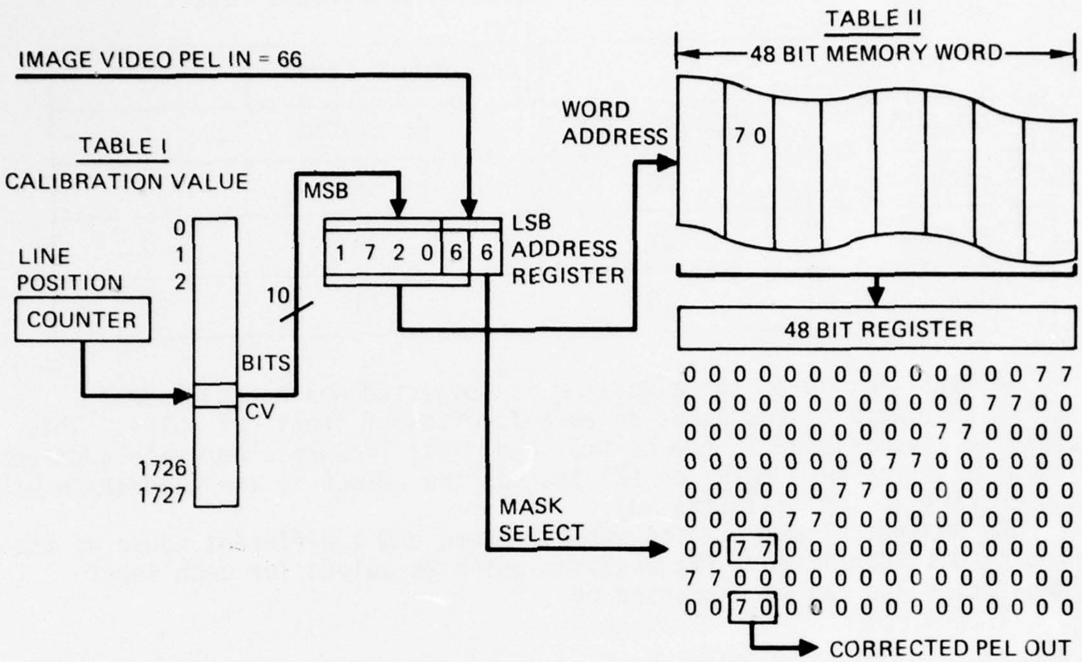


Figure A3. Correction algorithm.

Accomplishments Within Reporting Period

Although the algorithm works well to first order, detailed investigations in the reporting period uncovered a number of areas in which second-order improvements can be made. These problem areas are discussed below and some tentative methods for dealing with them are presented.

Problem Area 1—Average Background Level

An observed characteristic of the correction algorithm is that the overall background level is increased a small amount after correction. If it is determined that true grey scale images must be reproduced accurately with a multilevel output printer, then a modification to the algorithm will be necessary.

The average background level, before and after correction, has been examined to determine the extent of the error. Preliminary data have shown that the background level can be increased by several levels, and that the amount of the increase is not constant. These data were obtained by capturing and correcting three images categorized by low, medium, and high contrast.* Table A1 summarizes the results.

*Contrast is also referred to as high (black/white), medium (black/grey), and low (grey/grey).

Table A1. Effect of correction on background level.

	Background Level		
Contrast	Uncorrected	Corrected	Δ
high	46	50	4
medium	37	39	2
low	18	19	1

A modification to the algorithm is suggested which would add a subtractive term to the equation as a function of input pel value. This could be accomplished in one of two ways: (1) include a separate subtract function in the data path; or (2) include the effect in the generation of the entries in table II (fig A3).

An analytical calculation was performed and a different cause of the problem was identified. The equation which is solved for each input image pel value can be expressed by

$$P_{out_i} = \left(\frac{63\,\ell}{\sum_{n=1}^{\ell} PW_i} \right) P_{in_i} \tag{A1}$$

where

P_{out} = corrected pel out

P_{in} = input pel

i = line position index

PW = white standard pel value

ℓ = number of white standard lines summed

In the simplest case, in which $\ell = 1$, this reduces to

$$P_{out_i} = \frac{63}{PW_i} \times P_{in_i} \quad . \tag{A2}$$

Clearly, if PW = 63 (the maximum value), the input value is not changed by the correction. This is the desired condition in the center of the image where none of the errors previously described should be significant. If, however, the center portion of the white standard curve does not approach the maximum value, then the average background level of the image will be increased by the correction. In order to test this hypothesis,

three similar typed pages were scanned which had different contrast ratios. An illumination profile was plotted in an area of each image which was all background. Each plot represents a 16-line summation through that area. These plots are reproduced in figure A4 (A - C) for high-, medium-, and low-contrast images. Intensity values picked off these curves at three different pel positions are summarized in table A2. The relative brightness values read from the curves have been converted to absolute brightness values in table A3. The fourth entry in tables A2 and A3 is the white standard value at the same pel positions (fig A5).

Table A2. Relative intensity from illumination profile curves.

Pel Position	Contrast			White Standard
	Low	Medium	High	
216	0.25	0.51	0.63	0.79
648	0.28	0.58	0.75	0.92
1080	0.30	0.60	0.80	0.96

The absolute intensity values of table A3 are calculated by multiplying the relative intensity values (table A2) by 63 (the maximum value).

Table A3. Absolute intensity values — uncorrected.

Pel Position	Contrast			White Standard
	Low	Medium	High	
216	16	32	40	50
648	18	37	47	58
1080	19	38	50	60

The effects of the correction algorithm may be calculated by solving equation (A2) for the corrected pels from the values of table A3. The results of this operation are listed in table A4 along with the differences between the corrected and uncorrected pel values.

Table A4. Corrected pel values — calculated.

Pel Position	Contrast						White Standard
	Low	Δ	Medium	Δ	High	Δ	
216	10	4	40	8	50	10	50
648	20	2	40	3	51	4	58
1080	20	1	40	2	53	3	60

Two features of these results are of interest: (1) The correction process does flatten the background brightness level across the scan line; and (2) in all cases, the maximum background level is increased. This agrees closely with previous data shown in table A1.

If it is determined that the average background level must not be increased by the correction algorithm, then a modification to the hardware or procedure is required. From equation (A2), if the white pel (PW) value near the peak of the white standard curve is forced to be equal to the maximum value (63), then the equation reduces to the trivial but desired case of $P_{out} = P_{in}$.

This could be accomplished in one of two ways. The easiest is to assure that the acquisition system is set up to just saturate the scanner and A/D dynamic range during capture of the white standard. This may be undesirable, however, since the fine structure in the illumination curve would be lost.

An alternative is to capture the white standard slightly below the maximum value and add a linear offset to approach the desired level. This approach was tested on the previous data by modifying the correction equation to include a linear offset of +3 levels. The equation becomes

$$P_{out} = \frac{63}{PW + 3} \times P_{in} \quad . \tag{A3}$$

The previous correction calculations were repeated with equation (A3) and resulted in table A5.

Table A5. Corrected pel values — modified.

Pel Position	Contrast						White Standard
	Low	Δ	Medium	Δ	High	Δ	
216	19	3	38	6	48	8	53
648	19	1	38	1	49	2	61
1080	19	0	38	0	50	0	63

It is clear that at pel position 1080, where the illumination peak occurs, no background level change occurs. Also, the uniformity of the corrected background level is maintained and may be even better than before.

In a realized EMS image acquisition system this calculation could easily be performed by the control computer as part of the calibration and setup procedure.

Problem Area 2 — Odd/Even Response Considerations and Correction Effects

a. Problem Discussion. A great deal of interest has been expressed in a certain characteristic of imaging devices which use more than one output CCD shift register. A potential problem exists when the charge transfer efficiencies of the different output paths are not equal. This is especially true in a device like the Fairchild CCD121H, in which the two output registers are multiplexed to a single output pin. In this case, provision is not made to adequately trim the drive voltages and clocks to balance the outputs.

In order to gain increased understanding of the odd/even problem, a new technique has been devised and programmed on the ICAS. For a selected scan line in a white standard image, the difference between each odd numbered pel and its previous even neighbor was plotted. These data clearly show that the odd pel outputs are slightly below the even pel outputs. The difference plots are shown in figure A6. The RMS value of the differences was calculated to be

$$\left(\frac{(2)(+1)^2 + (150)(-1)^2 + (4)(-2)^2}{2 + 150 + 4} \right)^{1/2} = 1.03775$$

and the mean value is

$$\frac{(2)(+1) + (150)(-1) + (4)(-2)}{2 + 150 + 4} = \frac{-156}{156} = -1.0 \quad .$$

Since this method removes most of the illumination effects from the data, the errors represented are due to time-dependent white noise and nonuniformities in imager response.

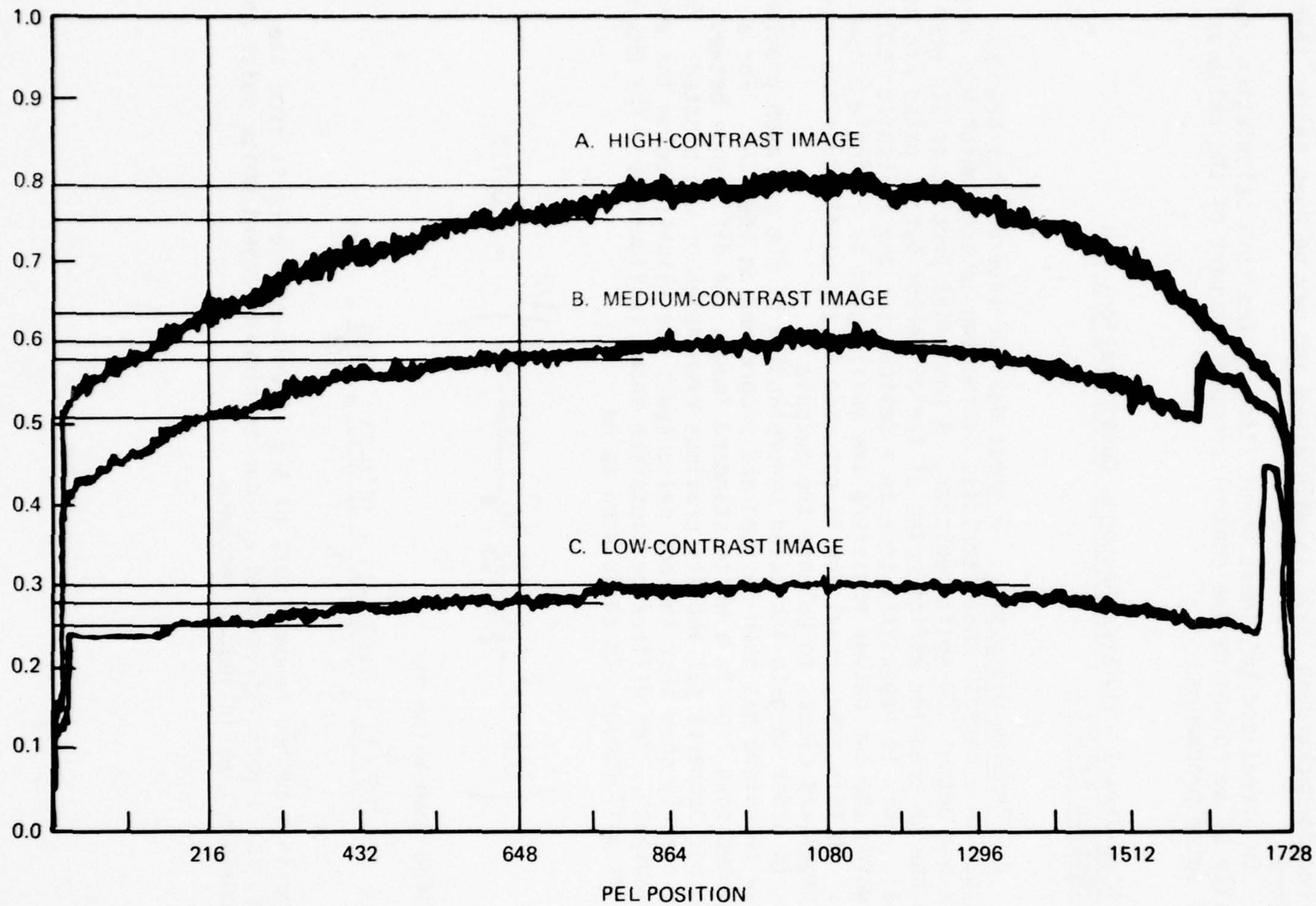


Figure A4. Illumination profiles of background areas of typed pages — high-, medium-, and low-contrast images.

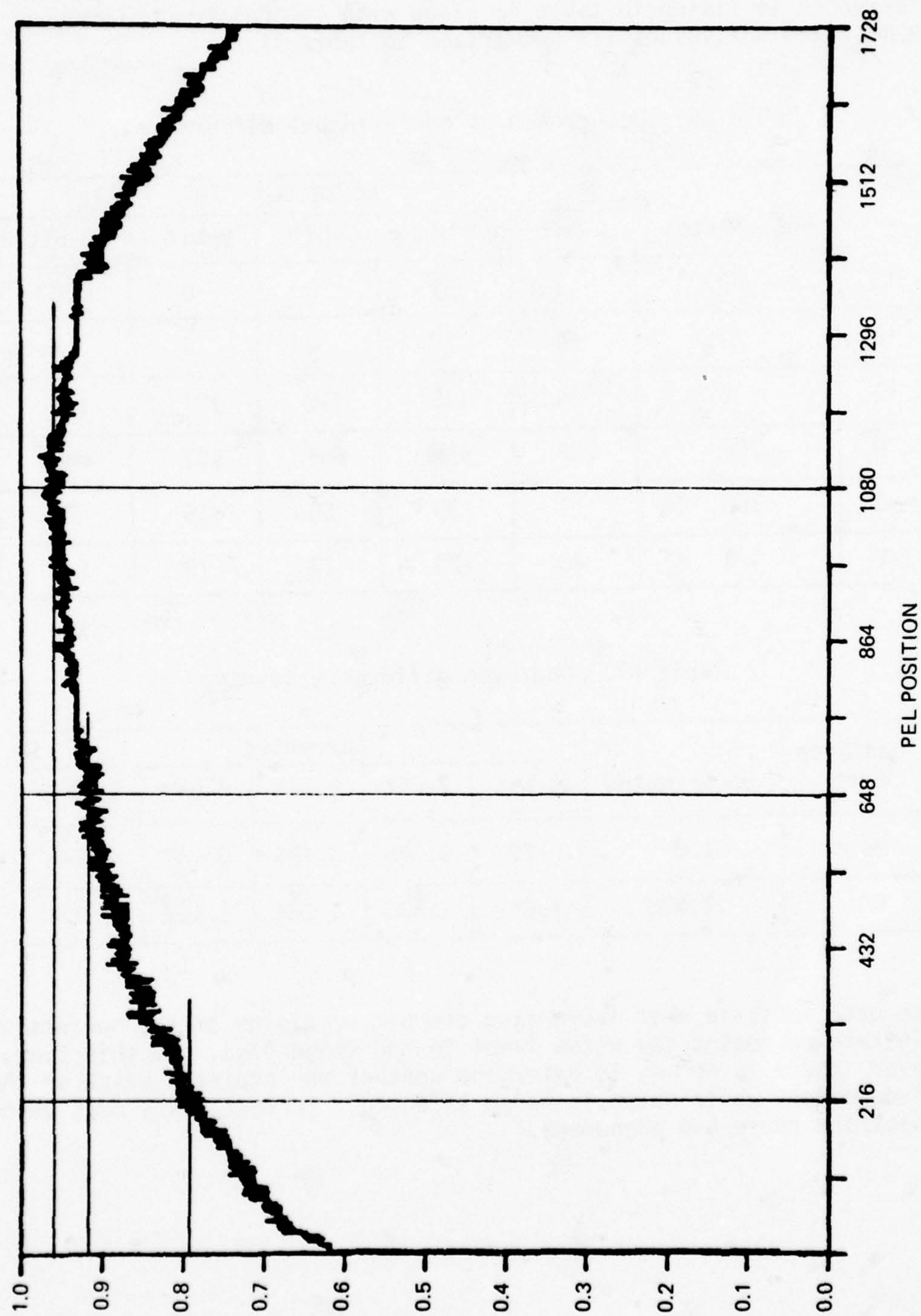


Figure A5. Illumination profile of white standard.

b. Correction Effects. The odd/even test was repeated an additional five times on corrected images to determine the effects on correction bit precision (fig A7 - A11). The occurrence of odd/even differences is listed in table A6 along with the uncorrected data. The mean and RMS values are summarized in table A7.

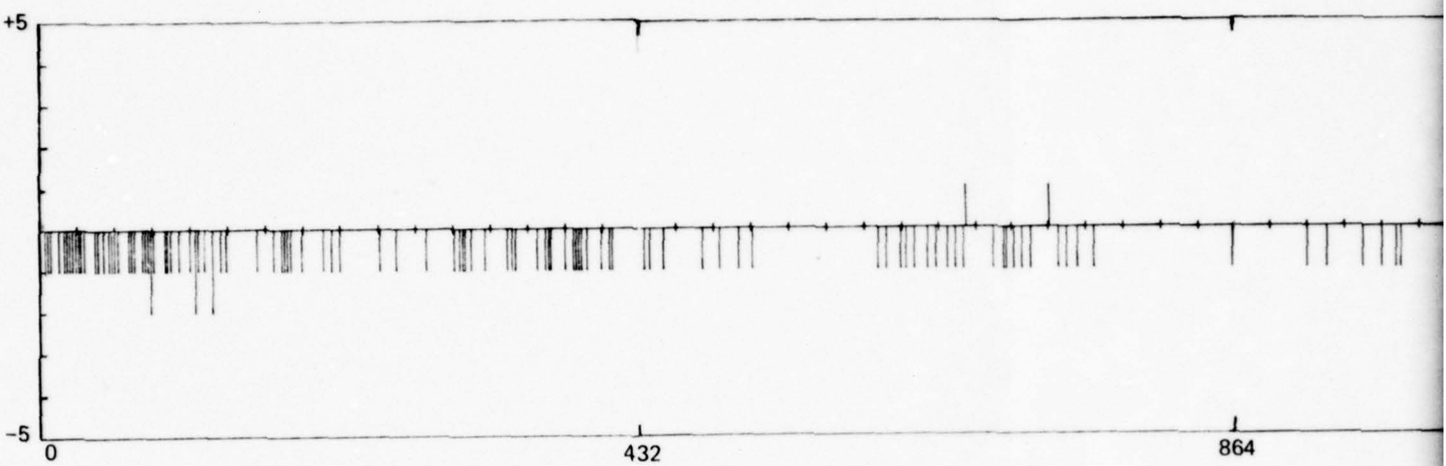
Table A6. Occurrence of odd/even pel differences.

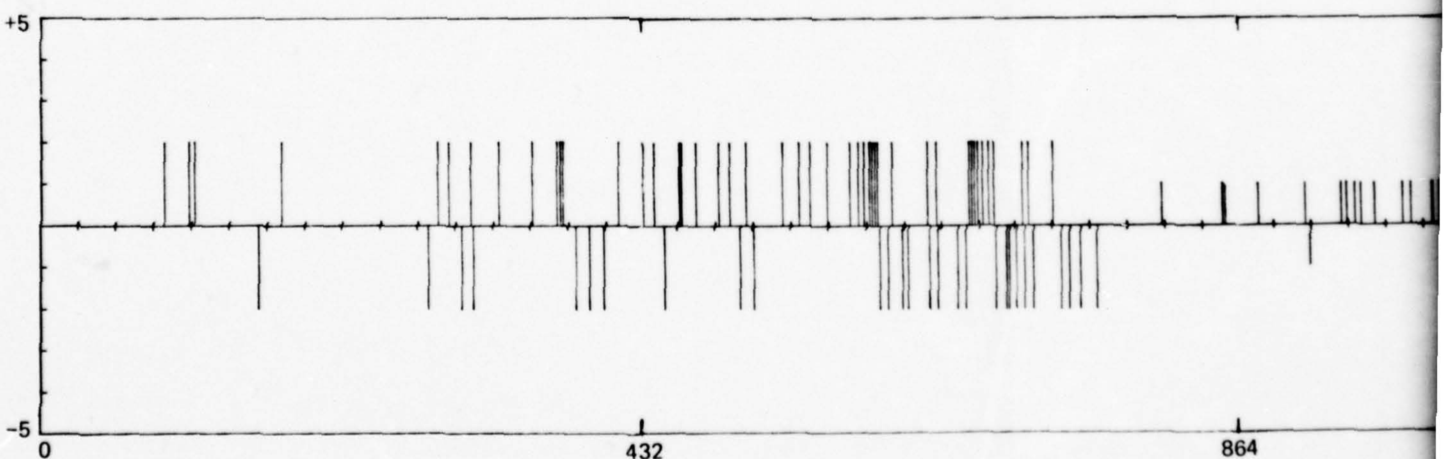
	Uncorrected	Corrected				
		6-bit	7-bit	8-bit	9-bit	10-bit
+3	0	1	1	0	0	0
+2	0	54	22	6	4	1
+1	2	24	115	116	121	115
0	708	736	658	669	661	668
-1	150	1	39	56	65	71
-2	4	48	29	17	13	9

Table A7. Odd/even difference summary.

Odd/Even Error	Uncorrected	Corrected				
		6-bit	7-bit	8-bit	9-bit	10-bit
Mean	-1.0	0.297	0.316	0.195	0.187	0.143
RMS	1.038	1.858	1.335	1.164	1.119	1.074

These data indicate that increasing the bit precision of the correction definitely decreases the noise level in the image data. At this time, however, there is no way to determine whether the odd/even noise or the time-dependent white noise is being affected. Further tests must be done to separate these two phenomena.


+5
-5
0
432
864


+5
-5
0
432
864

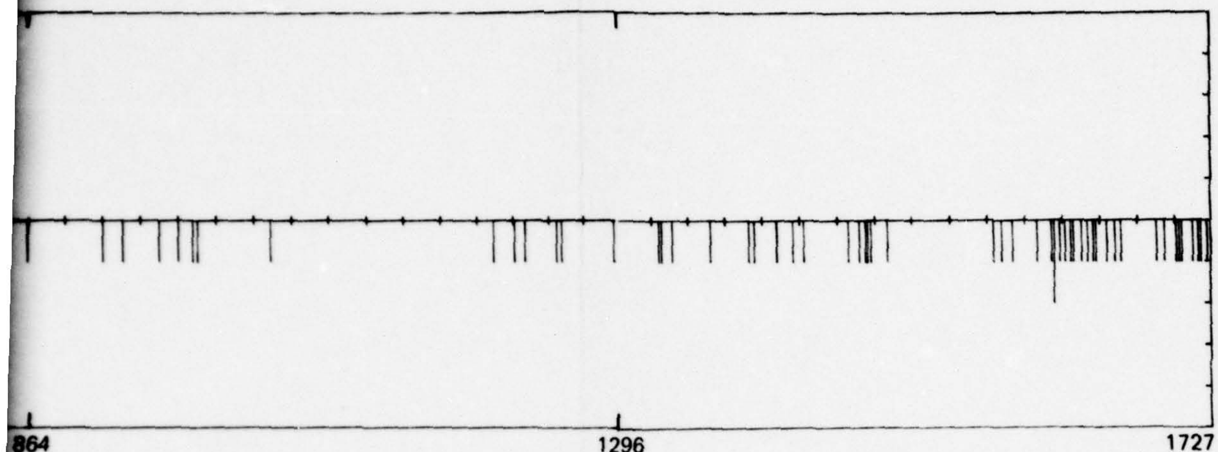


Figure A6. Difference plot, odd and even pel outputs, uncorrected.

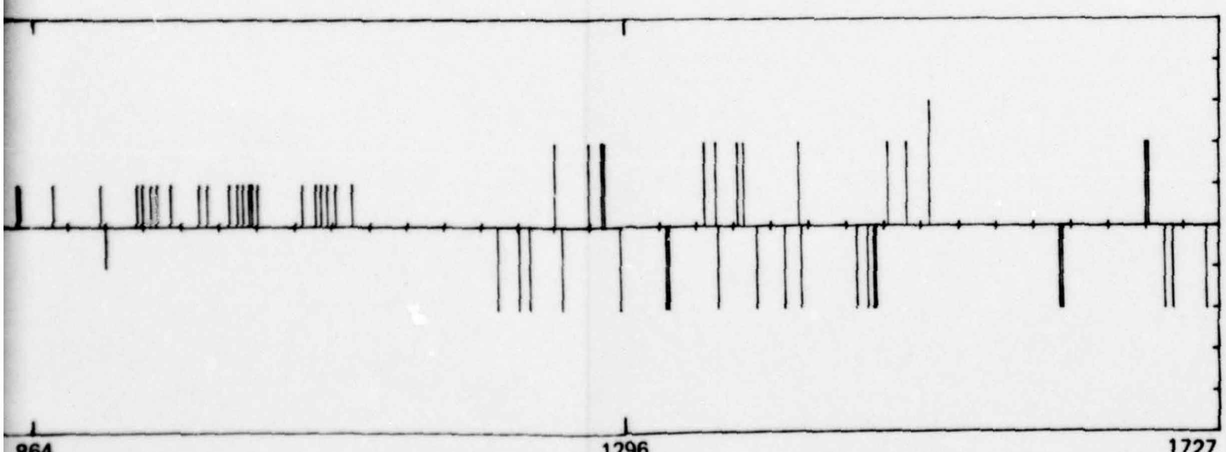
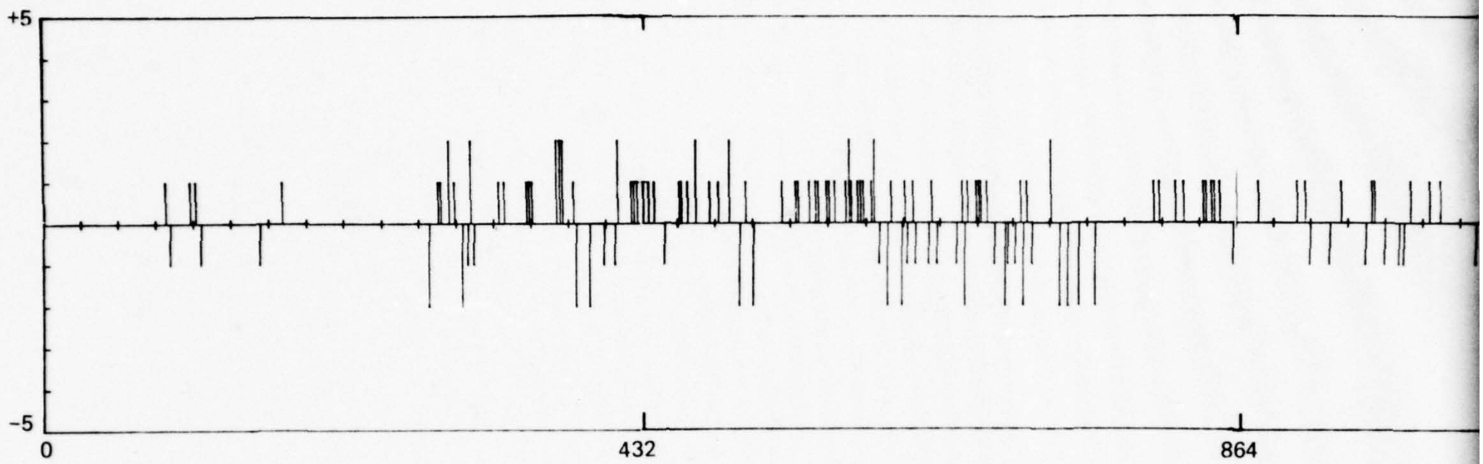


Figure A7. Difference plot, odd and even pel outputs, corrected, 6-bit precision.

2



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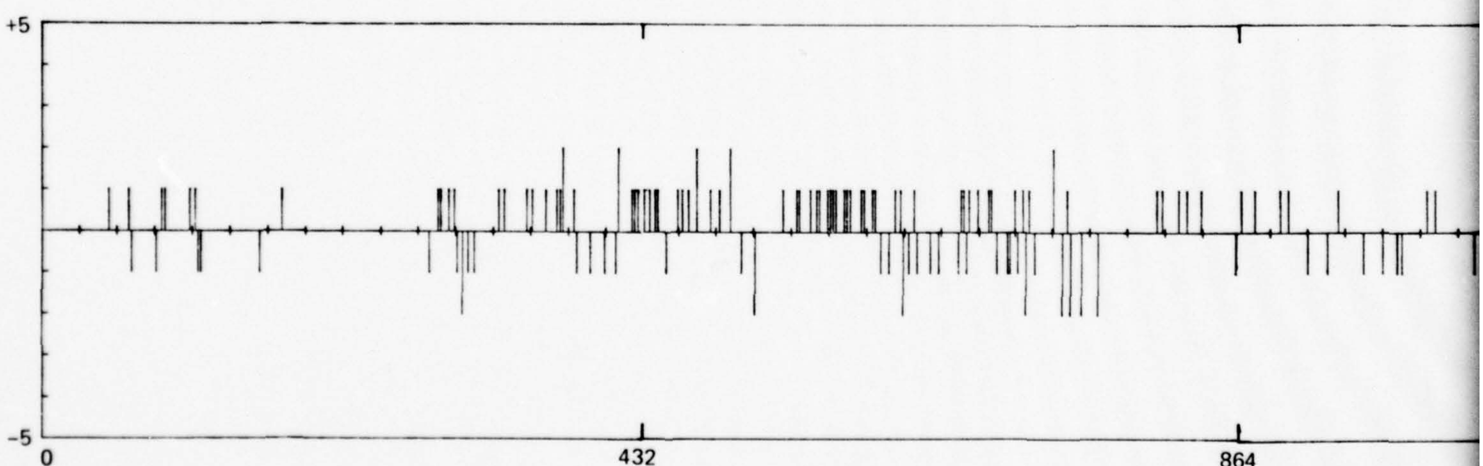

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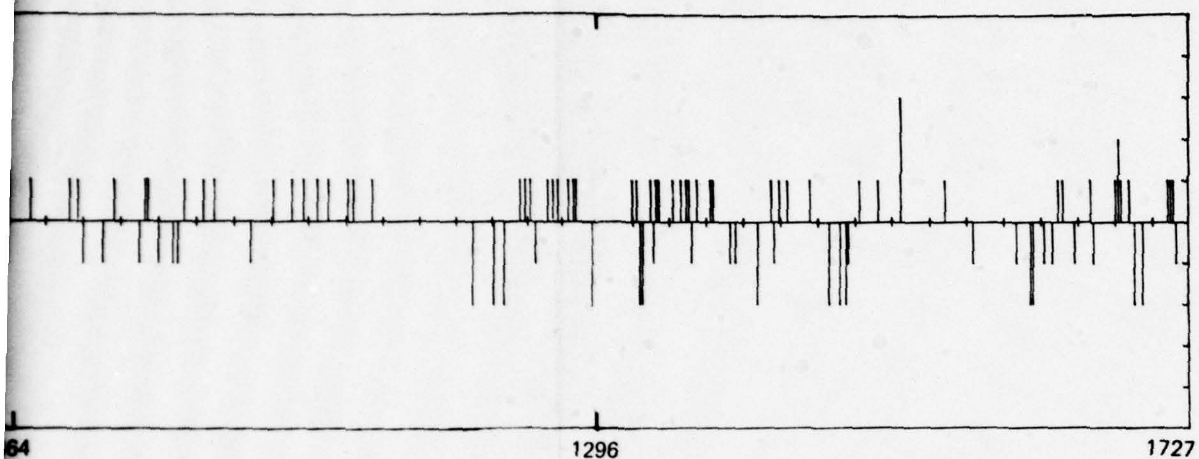


Figure A8. Difference plot, odd and even pel outputs, corrected, 7-bit precision.

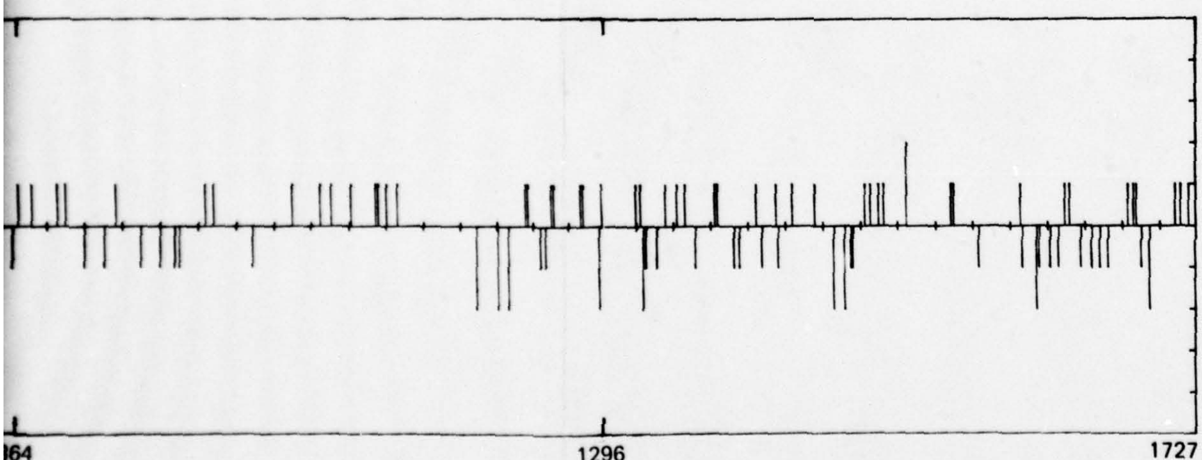
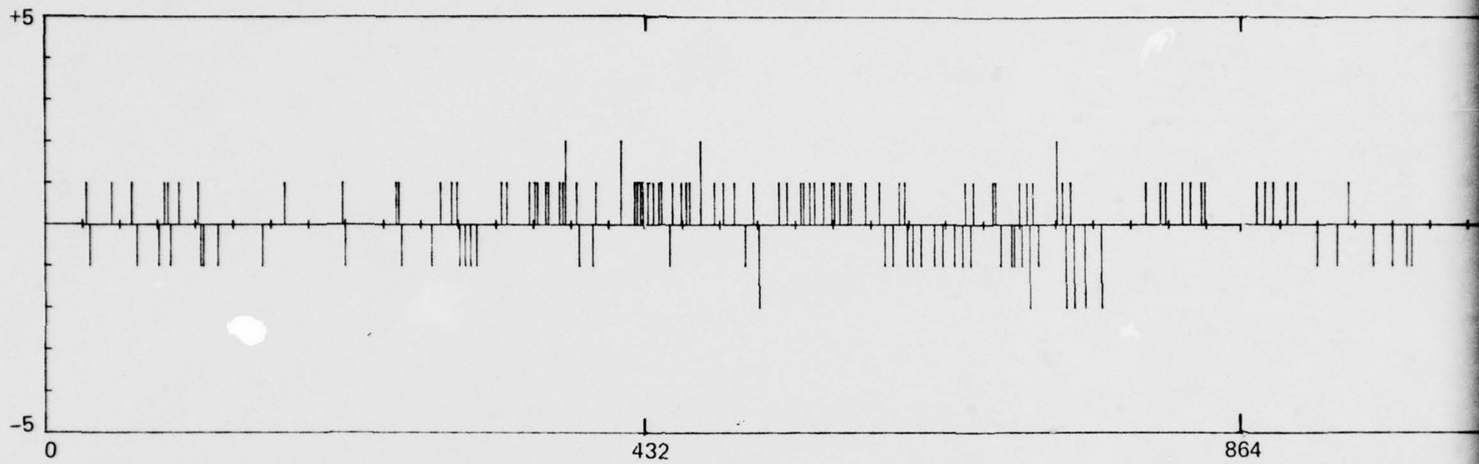


Figure A9. Difference plot, odd and even pel outputs, corrected, 8-bit precision.

2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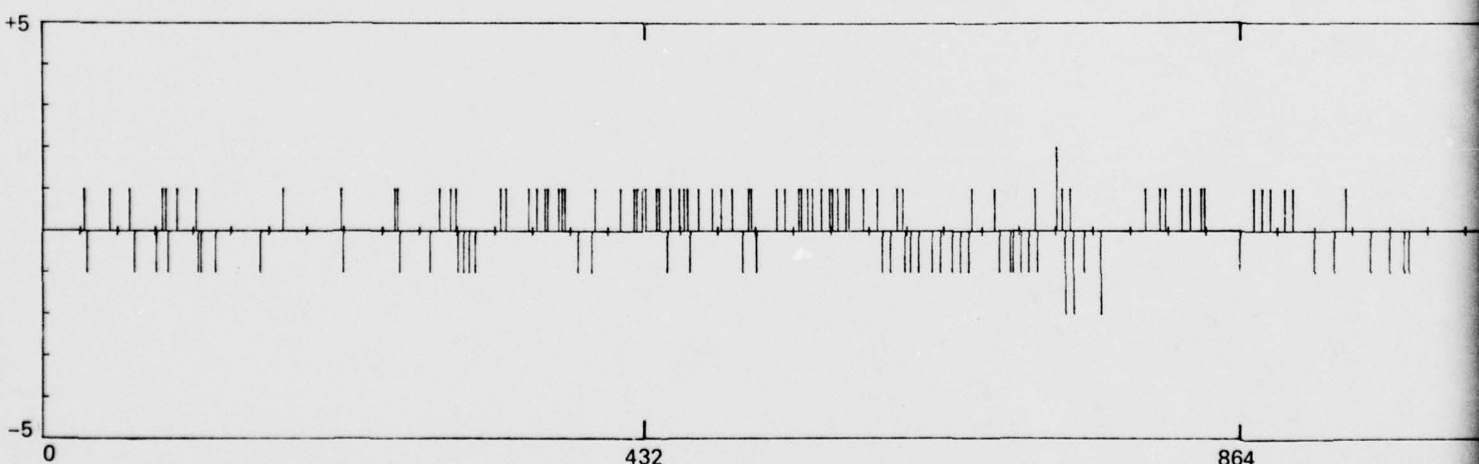
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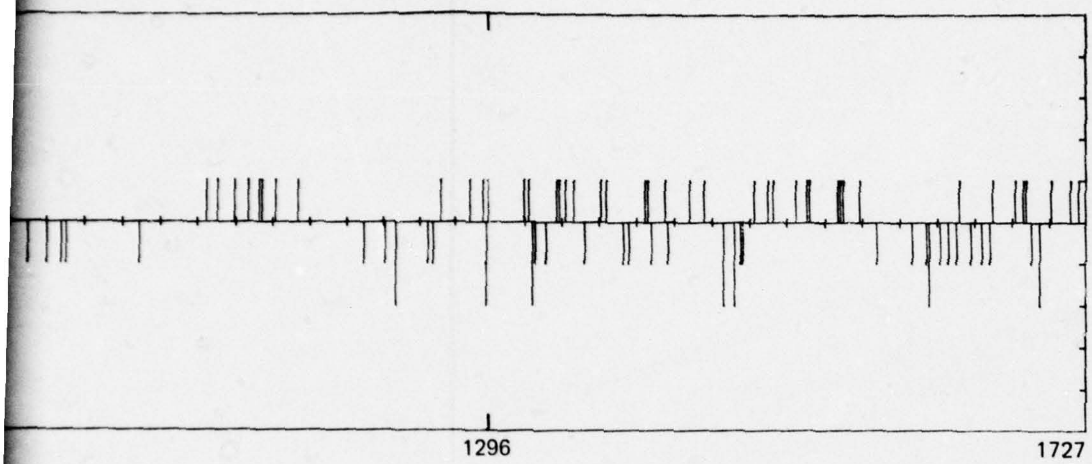

Figure A10. Difference plot, odd and even pel outputs, corrected, 9-bit precision.

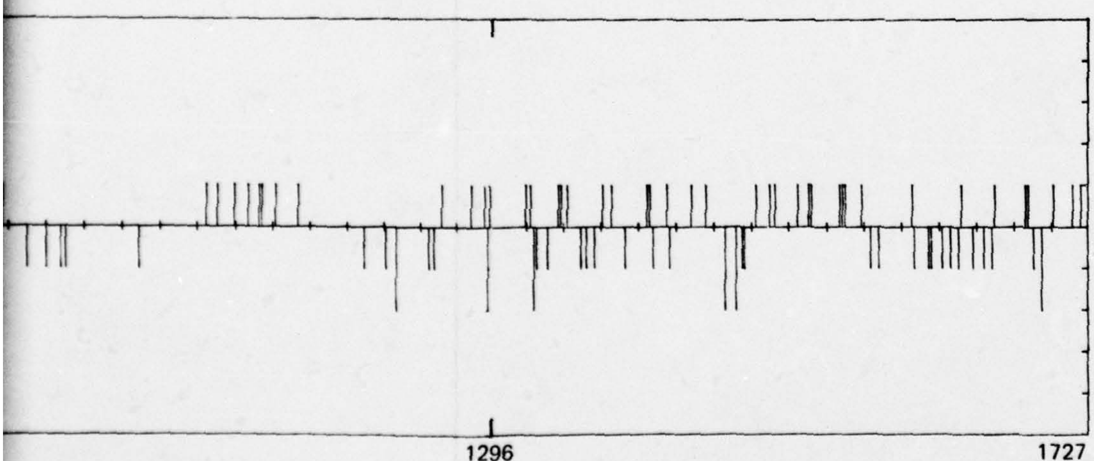

Figure A11. Difference plot, odd and even pel outputs, corrected, 10-bit precision.

2

Problem Area 3 — White Standard Uniformity

In previous work the acquisition of the white standard calibration curve was accomplished by scanning a target coated with barium sulfate ($BaSO_4$). This material was chosen because it has higher reflectance than any paper product and therefore could be used to establish maximum brightness level. It was also a convenient source for the white standard calibration curve used by the illumination correction algorithm. Unfortunately, however, all that the $BaSO_4$ target is suitable for is establishing a maximum white level. Another material with more uniform reflectance must be found to establish a standard reference for the illumination correction algorithm. A better material has been shown to be an unexposed sheet of glossy photographic paper. Although not so reflective as $BaSO_4$, photographic paper is superior to $BaSO_4$ with respect to surface uniformity.

Problem Area 4 — Setup Procedures

In order to take advantage of the uniformity of an improved white standard, a new calibration and setup procedure must be devised. At least two candidates are under consideration and one of these is currently being used. The required characteristics of both include establishing a maximum white level which is whiter than any possible input document, and generating the most accurate calibration curve possible to be used by the illumination correction algorithm.

a. Two-Target Method. In the two-target method, the $BaSO_4$ standard is used to establish the maximum white level as previously implemented. In generating the calibration curve, however, white photographic paper is substituted for the $BaSO_4$. In this step, a cleaner white standard curve is produced but at lower amplitude. This problem can be overcome either by adding an appropriate linear offset to the calibration curve or by temporarily increasing the light intensity during the acquisition of the calibration curve.

b. Neutral Filter Method. In the neutral filter method, the white photographic paper is used for both setup steps. The maximum white level is first established and then the calibration curve is acquired. All subsequent captures of image data are performed with a neutral density filter such that no image pel can exceed the value of the white calibration curve. This assures that all images are captured at a lower brightness than the white standard and thereby eliminates illegal corrected pel values. This method is currently being used for ICAS image data base acquisition and is operating satisfactorily.

Future Plans

Five modifications can be made to the equipment which will improve the performance of the illumination correction process. These modifications may not all be necessary to achieve a satisfactory degree of correction of the acquired image for display, data compression, and printing. These are discussed in the following paragraphs more or less in order of decreasing priority.

White Standard Uniformity

No correction can be made to the image response profile unless performance of the system with a target of known reflectance characteristics can be repeatably measured. For ease in calculating system response, this standard should also have extremely good uniformity and efficiency of reflectance when scanned at high resolution with incident illumination having spectral content lying anywhere in the visible color spectrum. The Eastman type 6080 White Reflectance Coating ($BaSO_4$) has about 99.1% to 99.4% reflectance across the visible spectrum.

Although considerable care was taken in depositing the white standard material on the target plate as directed, some nonuniformity was noticed. The major cause was cratering of the $BaSO_4$ resulting in shadows noticeable at high resolution.

The photographic paper substitute now used has excellent uniformity but has the disadvantage that its reflectance is lower than that of $BaSO_4$. This is now overcome by use of the neutral density filters but requires a higher illumination source or slower scanning speed. An effort will be made to obtain a higher reflectance material with good uniformity or to refine the process of applying the Eastman $BaSO_4$.

Amplifier Performance

Noise and gain fluctuations in the video amplifier can cause serious errors in the captured and digitized values of pel brightness Some tests have been run that show reasonably good agreement between two sets of digitized values of a line of captured image with the drum of the LDTB locked at rest. When the video amplifiers used in the Fairchild scanner (developed under USPS contract no. 104230-77-D-0463) are reduced to etched circuit boards, versions of these circuits will be substituted into the LDTB. Tests will be made to characterize the performance of several amplifier configurations.

Clock Driver Control

Evidence of the odd/even problem has been well documented in the preceding discussion. Bias voltages could be synchronously applied to the odd and/or even pulses to compensate for the differences, but this would be difficult to regulate over the wide dynamic range of imager response. The better way to control this problem is to separate the

driving clock and bias voltages applied to the odd and even channels. This allows individual adjustment of amplitude and level of the two sets of signals to produce uniform response over a wide range of video outputs. New clock driver circuits, using the better techniques of the Fairchild scanner, the RCA TDI clock driver, and present NOSC clock generator, will be used in the design of an improved clock source with separately controllable levels for odd and even transport registers.

Illumination Filter

At present, the reflected light received by the scanner from the white standard image has approximately 30% droop at the edges of a document page width. This is due to the finite length of the illumination source and drum, the cosine-fourth geometry of the optical system (and perhaps vignetting), and the decrease of light output from the slit-aperture fluorescent tubes in the vicinity of each end.

By experiment, a simple filter will be designed to attenuate the light output of the center areas of the tubes until a reasonably flat system response is obtained for the brightness values of the scanned white standard. Care will be taken not to reduce the light output at the tube ends so that the overall illumination efficiency will not be lowered.

High-Resolution A/D Converter

The present illumination algorithm can utilize a 10-bit (averaged) value of a pel brightness in computing a correction value. However it can only obtain a 6-bit value of the pel brightness of the scanned test image. It can be shown that a 6-bit number divided by a 10-bit number has little if any more significant certainty than the original 6-bit number. If, for instance, the odd/even problem amplitude value is approximately 0.5 level at 64 levels (which is the case), then a 7- or 8-bit A/D converter would show the variation as one or two levels. In other words, an 8-bit test image value divided by an 8-bit standard value can produce a correction of more significant accuracy than the "six divided by ten" version. Since the memory is designed to acquire only 6-bit pels, the 7- or 8-bit values would be rounded to 6 during correction by the use of appropriate values in table II of the correction algorithm.

The need for this modification is not conclusively known at this time. Correction of the odd/even problem with the new driver and amplifier electronics may preclude the need for incorporation. Also, the use of smoothing and/or filter algorithms may remove the objections to odd/even problems as they affect compressibility.

APPENDIX B:

DOCUMENT DATA BASE
PRELIMINARY REPORT

by

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INTRODUCTION

One of the main goals of the current NOSC/USPS program is the development of an algorithm which will classify images into two or more types, such as typewritten/handwritten and continuous tone. As part of this task, a data base will be generated consisting of approximately 200 images which will be digitized and stored on magnetic tape for analysis. This report describes the procedure for acquiring the data base and the different categories of images which will comprise it.

PURPOSE

It is the purpose of this task to develop an algorithm which will allow the automatic classification of images into two or more categories. To do this, a set of representative characteristics will be obtained from image samples which are pregrouped into about 20 arbitrarily chosen categories or types. These characteristics will be examined in order to find the ones that differ sufficiently from one image type to another. Another part of the problem is to determine how many distinct image types exist into which these images may be grouped.

DATA BASE DESCRIPTION

The data base (thus far) is organized as approximately 20 classes of documents, each class containing possibly 10 documents. The class descriptions are as follows:

01	Signed typed pages, no logo
02	Unsigned typed pages, no logo
03	Typed pages, black/white logo
04	Typed pages, color logo
05	Short typed pages, no logo
06	Handwritten pages
07	Carbon copies of typed pages
08	Onionskin – original typed pages
09	Onionskin – carbon copies
10	Halftone reproductions
11	Black/white photographs
12	Color photographs
13	Image standards
14	Forms – blank
15	Forms – filled out
16	Engineering drawings
17	Multilevel/multicolor circulars
18	Typed envelopes
19	Handwritten envelopes
20	Typed window envelopes
21	Address markup envelopes

As image samples are added to each document class, they are given a class number followed by a sequence number; eg, 01-03 would be assigned to the third document in class 1, which is signed typed pages, with no logo. A set of about 200 documents from a test deck prepared by Fairchild Imaging Systems has been added to this data base. Some of the test results from the analysis of these are shown in this appendix.

PRELIMINARY EVALUATION CHARACTERISTICS

The ultimate number of image characteristics examined will be determined by the intermediate results of this investigation. That is, after a set of statistics or characteristics has been examined, it may become apparent that still different characteristics need to be investigated. If this is the case, the images in the data base will be analyzed again with respect to the new characteristic(s). After a number of iterations, it is planned that an algorithm can be formulated to determine by use of a minimal set of evaluation characteristics which of at least two different categories the images fall into.

As an example of this procedure, the first set of statistics that will be examined is the pel brightness statistics (PBS). The PBS should contain certain identifying features that will help in separating primarily bilevel images from continuous-tone photographs. Examples of ideal PBS histograms for bilevel and continuous-tone images are shown in figures B1 and B2.

Figure B1 contains a model PBS histogram for a typewritten page. Here, curve A represents the statistics of pels occurring at more or less random brightness levels due to the nature of pels falling on character edges. Curve B is a measure of both the average reflectance level of the ink on the page and the total area of the paper covered by ink. Curve C is the average white level of the paper background.

Figure B2 shows a possible continuous-tone PBS histogram. If the image is composed of very many edges, a curve A will be generated like that in figure B1. As compared to a typewritten page, a photograph is expected to contain mostly intermediate grey or dark areas, resulting in a histogram of the same general shape as curve D.

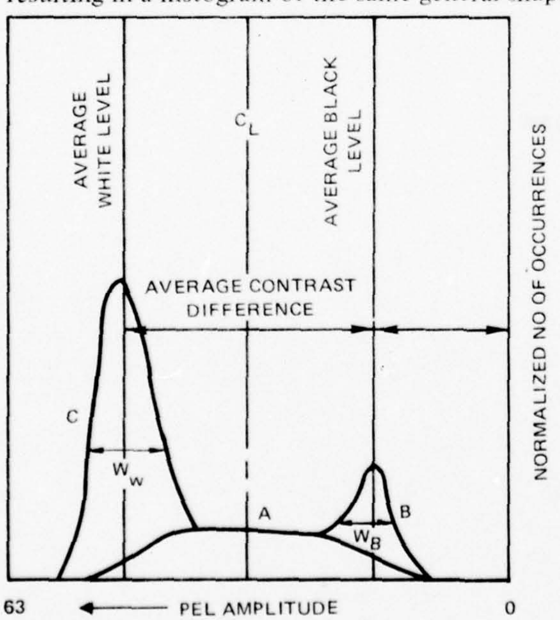

Figure B1. Ideal typewritten image pel brightness histogram.

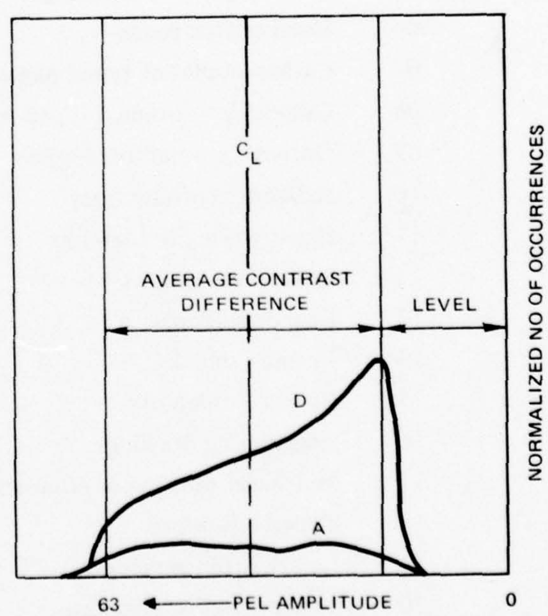

Figure B2. Ideal continuous-tone pel brightness histogram.

The statistics obtained from the first pass through the image data base will be analyzed in an attempt to exploit the differences in the PBS in order to establish at least the two classes of images: bilevel versus continuous tone.

Another set of statistics will be obtained by use of a spatial feature identification algorithm. This algorithm computes the cumulative brightness of each line in an image by summing the individual pel brightness values across the line. An example of this is shown in figure B3. Each of the six characters in this figure was divided into a matrix of areas corresponding to 5-mil spot sizes on actual typewritten material scanned at 200 pels per inch.

Assuming that this image is black and white only (1 bit per pel), the pels are counted across each line and the sum is plotted on the right side of the figure, expressed as a percentage of the total number of pels per line. If this array of sums is then examined by spectrum analysis techniques, two predominant spatial frequency components will be seen. One is related to the spacing of the typewritten lines (F_1) and the other to the horizontal line structure spacing within the characters on a line (F_2).

Figure B4 is the result of applying this algorithm to an actual digitized image. This image was digitized to 6 bits per pel and the 6-bit numbers were summed across each line to obtain the relative brightness sums. The result is clearly consistent with the model shown in figure B3.

It is felt that the relative brightness sums for non-typewritten images will be sufficiently different from those for typewritten images that, by looking for a few key spatial frequencies in the data, a determination can be made as to the category of an image, typewritten versus non-typewritten.

PROCEDURE

The document data base may be considered to be a three-dimensional matrix, the three axes being document class, document sample, and evaluation characteristic. Also, each point within this matrix is a set of numbers comprising one particular evaluation characteristic or image statistic. Thus, with 20 classes, 10 documents per class, and five or six evaluation characteristics, the document data base will become rather large in terms of the volume of data to be stored for analysis.

It is not practical to consider storing each and every image that is digitized in both raw (uncorrected) and illumination-corrected form. However, for the first several images analyzed, the raw image has been stored on tape.

As images are scanned and analyzed, the statistics are stored on magnetic tape in the order in which they are acquired without regard to special ordering. A separate off-line data base catalog program is used to keep track of the location of the statistics. This catalog may then be searched automatically in any of a number of different ways. For example, the catalog may be searched for all statistics gathered on one particular image. The program then outputs the evaluation characteristics, tape number, and file number for all statistics gathered for that image.

To begin acquiring the data base, preliminary evaluation characteristics were chosen and all the images currently in the data base were scanned and analyzed with respect to the selected characteristics. This process will be repeated with new test image characteristics.

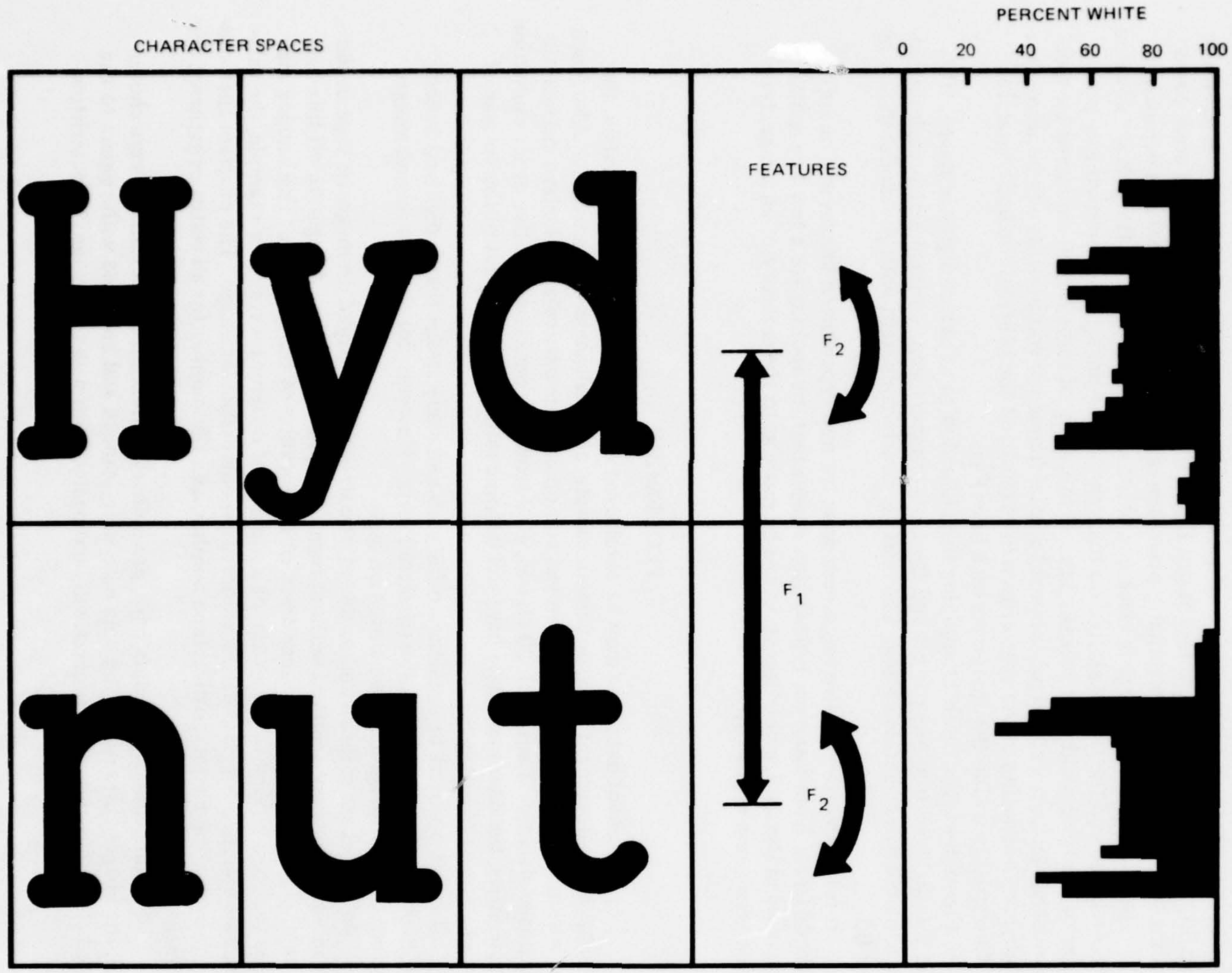

Figure B3. Document classification, typed page.

IMAGE
AREA SAMPLED

W. J. Miller, Director
ce of Advanced Mail Systems Development
1 Parklawn Avenue
ville, Maryland 20852

lemen:

This is a sample of the letter we propose to u
ndard" for imaging experiments at NELC, San Di
nade on a Wang System 1222 Dual Cassette Typew
h consists of a modified IBM Selectric typewri
ette holders, and a magnetic core memory capab
ing pages of data such as this letter. The ca
s are being made to store the data for each ch
nited States of America Standard Code for Info
rchange (USASCII) format. This is a standard
binary code for each character which is widely
stry. In USASCII form this page as written ca
tly defined by 15099 bits of data (excluding s
or header information). When scanned at 200
ure elements per inch with six bits per elemen
scale the page is defined by 22,440,000 bits.

By recording the contents of this letter on ca
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inals, all nominally exactly the same. Since
writer is an IBM Selectric it is also possible
ge the type font without changing the message.
possible to change ribbons (a five- or ten-mi
ss) to yield copies of differing colors. It

APPROXIMATELY 1000 pels

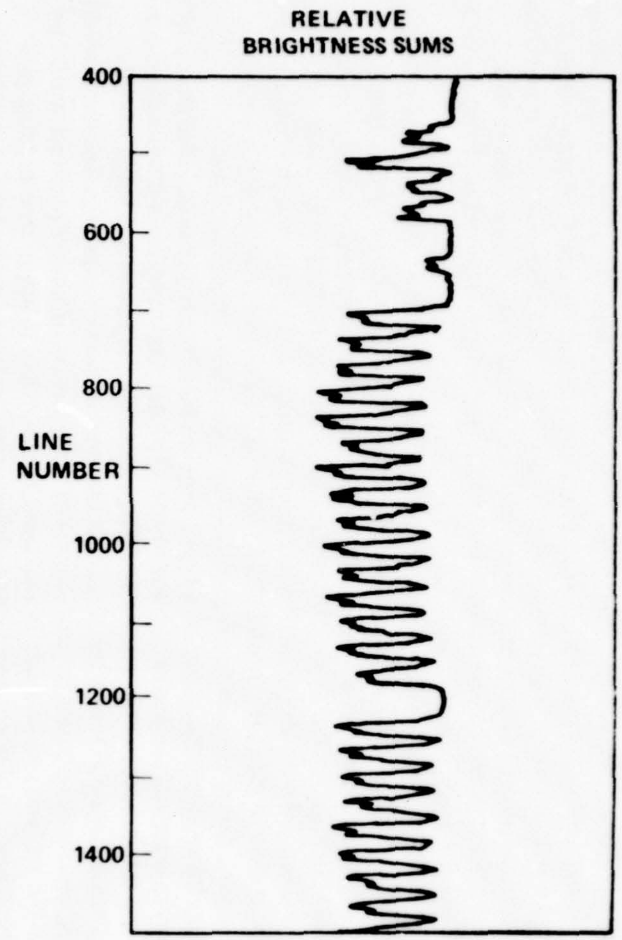


Figure B4. Vertical spatial frequency response.

PRELIMINARY ANALYSIS RESULTS

Because of the encouraging results obtained in the first spatial frequency test, it was decided to begin the analysis of a modest number of images from all classes, with the expectation that the relative brightness sums from non-typewritten pages will be sufficiently different from those of the typewritten images. The features of horizontal spatial frequency identification (SFI_h), vertical spatial frequency identification (SFI_v), and PBS may make it possible to classify an image as typewritten or non-typewritten. For this reason, samples from a number of image classes were acquired and analyzed to provide vertical and horizontal spatial frequencies and pel brightness statistics.

Figure B5 shows the format in which the results are presented. The upper right quarter of figure B5 contains a reduced reproduction of the image being analyzed. Immediately to its left is an area assigned to the SFI_v plot. Immediately below the image sample is an area allotted for the SFI_h plot. The lower left corner area contains the PBS. The lower right contains the document title, its identification number, the date of the scan, and the color content of the image, if any. Figures B6 through B26 represent 21 document analyses on various classes of images. This section of the report discusses the results of this analysis.

Figure B6 contains the image of a typed page on plain white paper and also the results of analyzing the digitized version of the document. The data have not been illumination corrected because this process would normally take place while the image was being passed through a prescan station. During this first pass the total dynamic range of reflectance would be unknown, and no corrections for unevenness of illumination or imager response would be included. If the analysis can be made in real time, it is possible to apply thresholding gain and level adjustments or any enhancement techniques as the image is acquired, depending on the results of the classification before this same image reaches the main scan station.

The results of the vertical and horizontal SFI analysis show a remarkable degree of correlation between rows and columns of typing on the page and the resulting horizontal and vertical brightness sums accumulated by the process. Also, the PBS provide the indication of typical pattern for a typed page. At approximately levels 44 to 48 there is a preponderance of pel sums which are, of course, a result of scanning the white paper. There exists a saddle point at approximately level 28 which represents an equal probability that one half of the pel area was on a black character stroke and the other was detecting the white paper substrate. The second peak at the right of the PBS indicates the sampling of ink area as a result of the typing. The area of actual typing (blackness) is approximately 4% of the total page area. It should be noted that on all PBS histograms, the ordinate or number of occurrences is plotted on a logarithmic scale.

The PBS are typical of those of many samples of typed pages. Software has been written to detect local peaks and local saddle points, but no overall software routine has been written to determine automatically the ratio of amplitudes or number of relative brightness steps between these features. It is contemplated that in the future it will be possible to design a very dependable algorithm for the detection of this class of documents through the PBS data.

The features, then, which are available to identify the presence of a typed page are: the SFI_v, which is clearly evident here; the SFI_h component, which is very evident here; and the typical PBS for a document containing predominantly white material and a single level of black ink, typing or otherwise.

It is therefore possible to utilize these three criteria, and these three criteria only, as a temporary set of standards for classifying pages into a typed page candidate category which may be subsequently submitted for potential optical character recognition (OCR) analysis.

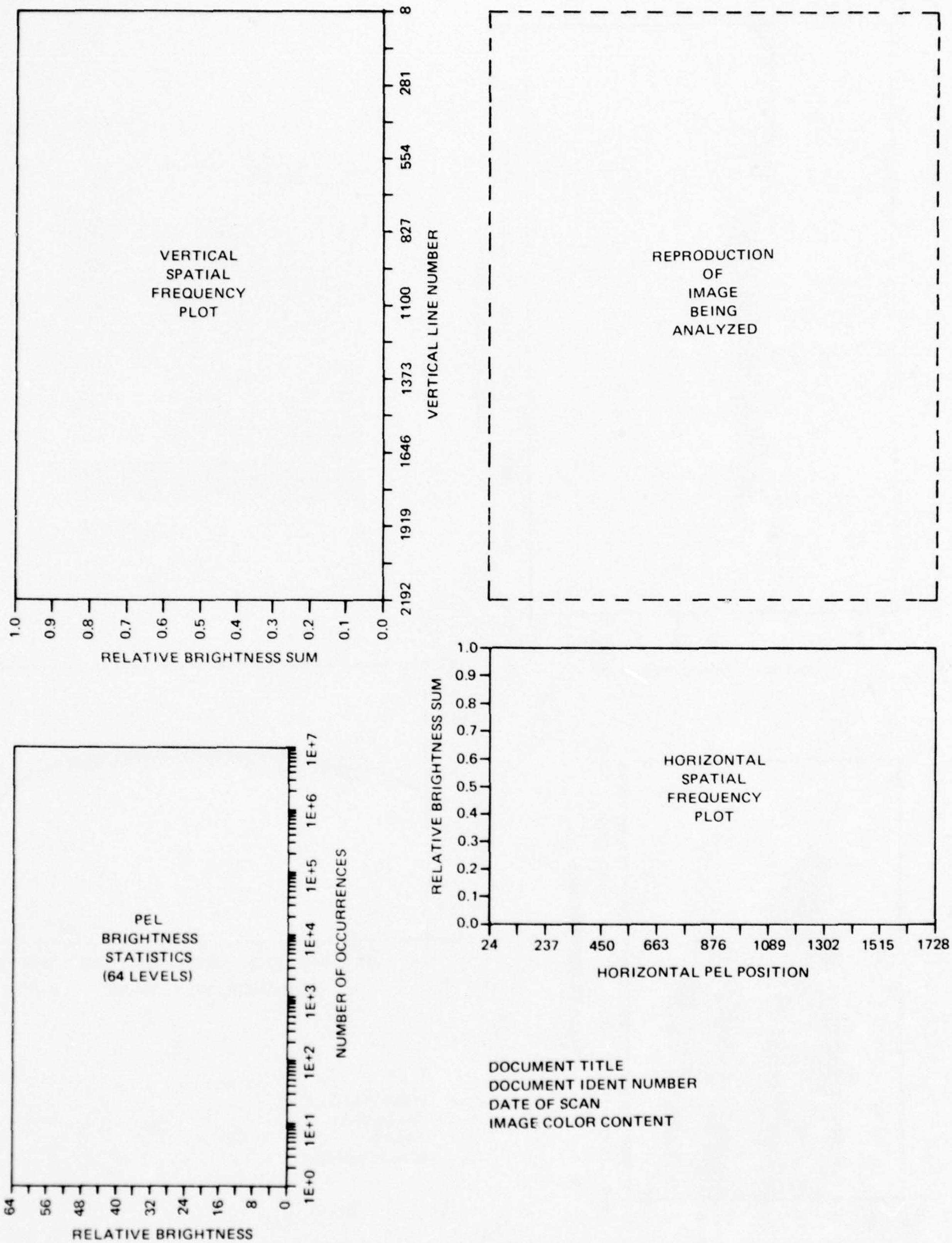
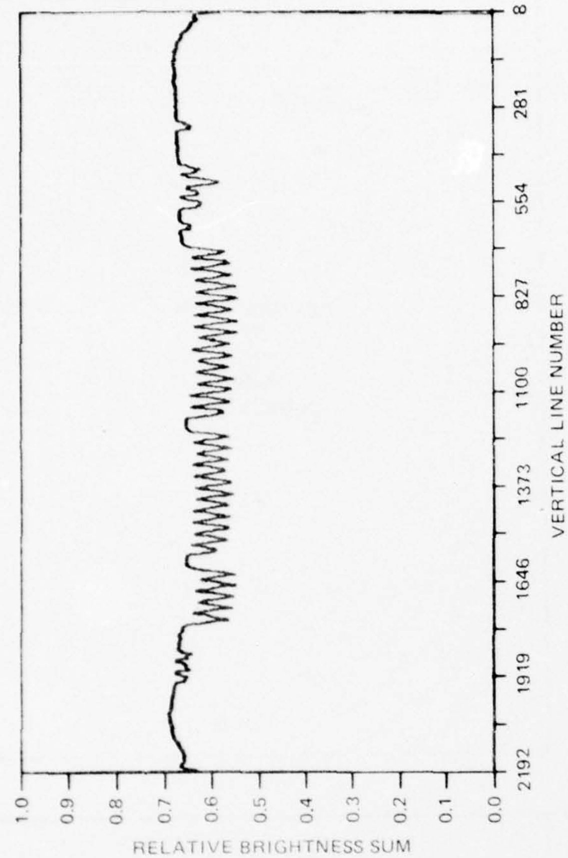


Figure B5. Document format layout.



22 February 1976

Mr. W. J. Miller, Director
Office of Advanced Mail Systems Development
11711 Parklawn Avenue
Rockville, Maryland 20852

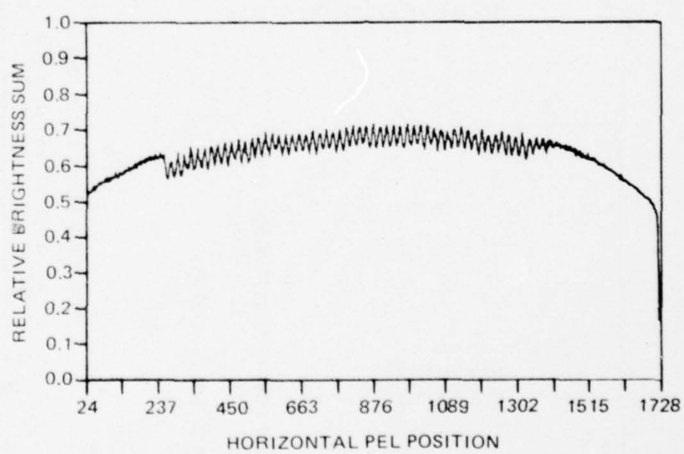
Gentlemen:

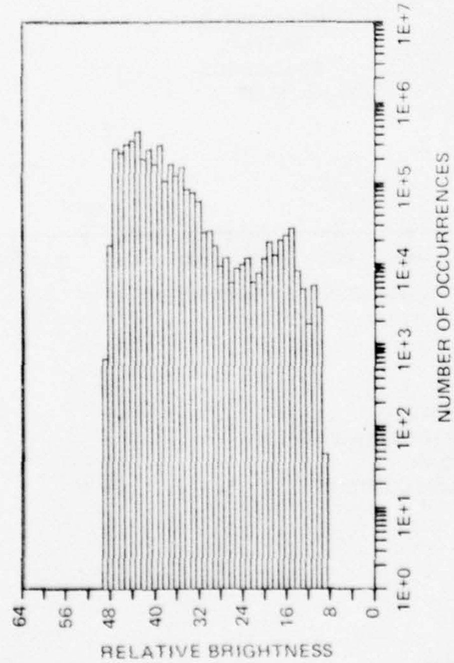
This is a sample of the letter we propose to use as a "standard" for imaging experiments at NELC, San Diego. It was made on a Wang System 1222 Dual Cassette Typewriter which consists of a modified IBM Selectric typewriter, two cassette holders, and a magnetic core memory capable of storing pages of data such as this letter. The cassette tapes are being made to store the data for each character in United States of America Standard Code for Information Interchange (USASCII) format. This is a standard seven bit binary code for each character which is widely used in industry. In USASCII form this page as written can be exactly defined by 15099 bits of data (excluding signature, logo or header information). When scanned at 200 x 200 picture elements per inch with six bits per element for grey scale the page is defined by 22,440,000 bits.

By recording the contents of this letter on cassette tape, it is possible to reproduce a quantity of duplicate originals, all nominally exactly the same. Since the typewriter is an IBM Selectric it is also possible to change the type font without changing the message. It is also possible to change ribbons (a five- or ten-minute process) to yield copies of differing colors. It is of course possible to write on all textures, colors and weights of paper with or without letter head. It will also allow copies of this text to be analyzed both with and without signatures of various colors.

This ability to provide complete parameter selection and consistency control for analysis of thresholds, contrasts, color separation, compressability coefficients, and character fonts will be of great benefit in quantifying the requirements of U. S. Postal Service Scanner technology.

Frank Martin
NELC Code 3100
Problem N451





WJM TYPED PAGE
IMAGE 02-01
7/26/78
BLACK, WHITE

Figure B6. WJM typed page, Image 02-01.

Figure B7 is almost identical to figure B6 except for the much darker impression of the typewriter keystrokes. The differences between figures B6 and B7 are only evident in the amplitude of the horizontal and vertical SFI waveforms. By the criteria that components of SFI_h and SFI_v which represent columns and rows of typed characters and the representative PBS bilevel histograms are present, this image also would be classified for thresholding and as a candidate for OCR processing.

It should be noted here that the amplitude of the vertical and horizontal spatial resolution responses can be affected by skewing of the paper. Horizontal and vertical spatial frequency characteristics will be much less pronounced when skewed lines of typing are encountered. Deskewing algorithms are often used to prepare digitized typed pages for optical character recognition (OCR). The use of such an algorithm would also improve the SFI responses at the same time.

Figures B8 and B9 are representative of another class of image documents, typed pages with signature and black and white logo. Throughout the typing portion, the same characteristics apply which were seen in figures B6 and B7; however, the logo does present some modification to the characteristics of the image.

Since both these figures support the criteria of a pronounced SFI_v, SFI_h, and bilevel PBS histograms, both documents would be submitted for threshold scanning at the main scanner station and for OCR processing.

Figures B10 and B11 are from another class of documents having color logos. In the case of figure B10, this logo is in the form of flags surrounding the perimeter of the document. In the areas of typing the vertical spatial frequency response is quite pronounced, probably because of the excellent alignment of the image document on the scanning drum. The SFI_h response is not nearly as pronounced and probably would not pass an automatic test for typed page SFI_h characteristics.

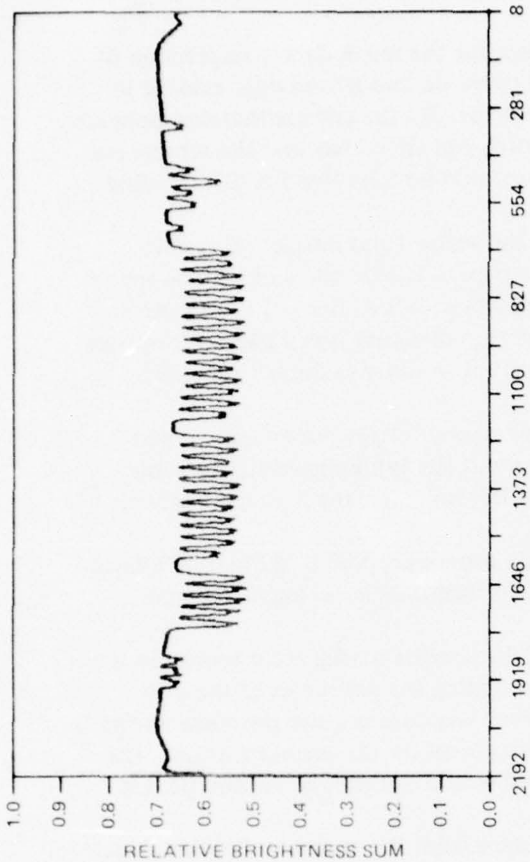
The PBS histogram contains grey scale information from the various reflection densities of the colored flags around the border and therefore tends to mask the characteristic bilevel form of the histogram which accompanies a normal typed page. Failing to pass two of the three required parameters for OCR submission, figure B10 would not be accepted. Figure B11, however, appears to have all the necessary characteristics and undoubtedly would be submitted for OCR processing.

Figure B12 is a handwritten letter written with ball-point pen. It has some of the elements of SFI_v and PBS histogram of the proper format but lacks SFI_h and would not be submitted for OCR processing.

Figure B13 is a black and white photograph of a large circuit board. This image does not pass any of the criteria for bilevel or OCR recognition classification. It does, however, show that some fine detail in photographs of man-made objects of this type may produce the proper characteristics of SFI and even PBS which would allow the document to be submitted for bilevel imaging and even OCR processing.

Figure B14 contains the IEEE facsimile test chart, which combines bilevel and continuous-tone imagery. The PBS histogram meets some of the characteristics of a bilevel image. The data also indicate the presence of lines of information in certain areas of the SFI_v. However, the amount of irregularity in the document would undoubtedly cause it to be rejected from bilevel scanning and being tested for OCR readability.

Figure B15 is an uncompleted form printed on dark green paper with black ink. Row and column lines in the form produce very strong perturbations in the SFI plots but do not have the spatial characteristics of typing. The dark green substrate causes the PBS histogram to exhibit a peak at about level 28 and to contain a peak of the ink response at around level 8.



22 February 1976

Mr. W. J. Miller, Director
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11711 Parklawn Avenue
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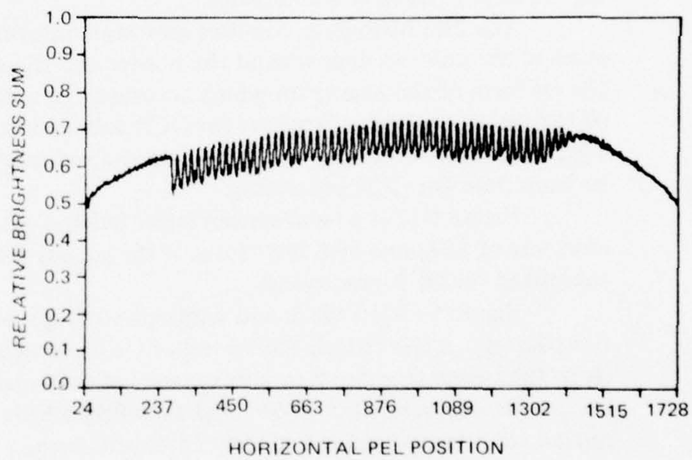
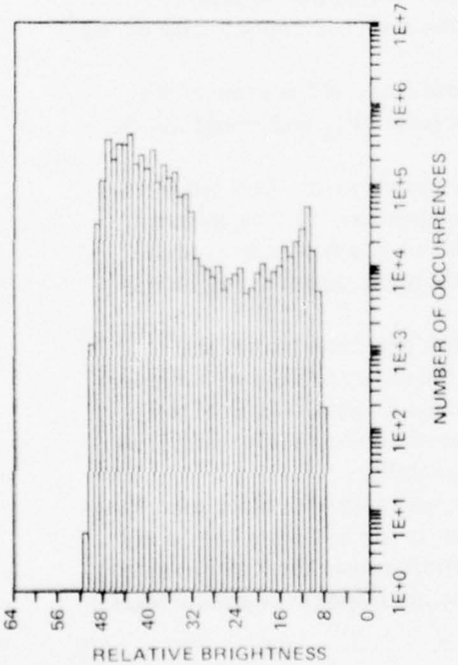
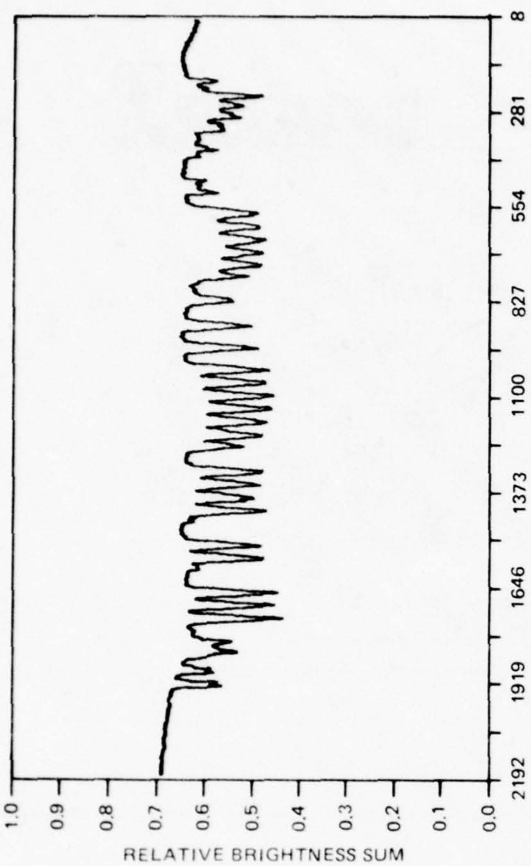
Frank Martin
NELC Code 3100
Problem N451

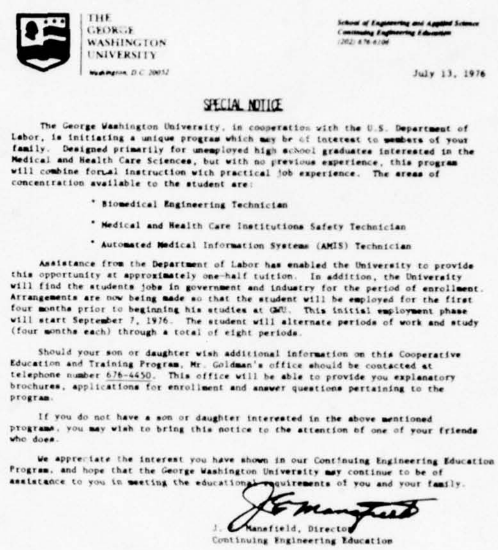




WJM TYPED PAGE
IMAGE 02-02
8/07/78
BLACK, WHITE

Figure B7. WJM typed page, Image 02-02.





THE GEORGE WASHINGTON UNIVERSITY

School of Engineering and Applied Science
Continuing Engineering Education

July 13, 1976

SPECIAL NOTICE

The George Washington University, in cooperation with the U.S. Department of Labor, is initiating a unique program which may be of interest to members of your family. Designed primarily for unemployed high school graduates interested in the Medical and Health Care Sciences, but with no previous experience, this program will combine formal instruction with practical job experience. The areas of concentration available to the student are:

* Biomedical Engineering Technician
* Medical and Health Care Institutions Safety Technician
* Automated Medical Information Systems (AMIS) Technician

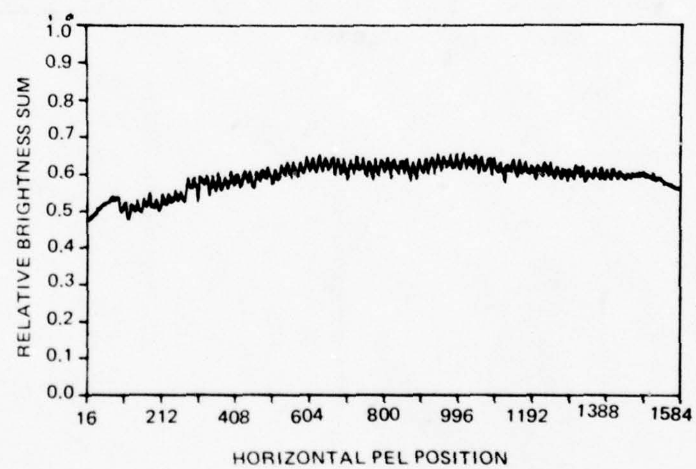
Assistance from the Department of Labor has enabled the University to provide this opportunity at approximately one-half tuition. In addition, the University will find the students jobs in government and industry for the period of enrollment. Arrangements are now being made so that the student will be employed for the first four months prior to beginning his studies at GWU. This initial employment phase will start September 7, 1976. The student will alternate periods of work and study (four months each) through a total of eight periods.

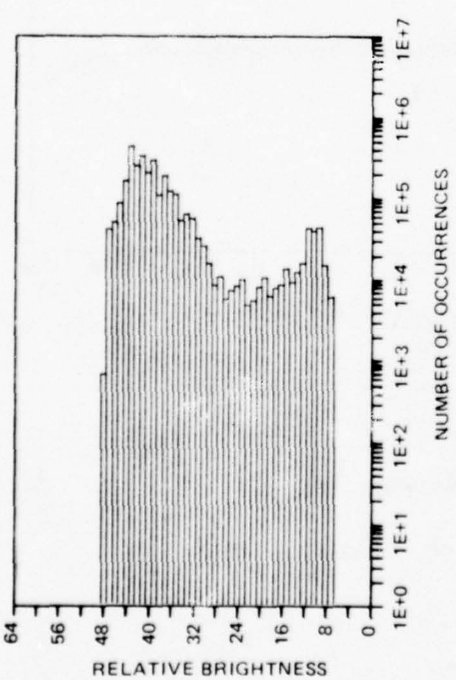
Should your son or daughter wish additional information on this Cooperative Education and Training Program, Mr. Goldman's office should be contacted at telephone number 676-4450. This office will be able to provide you explanatory brochures, applications for enrollment and answer questions pertaining to the program.

If you do not have a son or daughter interested in the above mentioned programs, you may wish to bring this notice to the attention of one of your friends who does.

We appreciate the interest you have shown in our Continuing Engineering Education Program, and hope that the George Washington University may continue to be of assistance to you in meeting the educational requirements of you and your family.

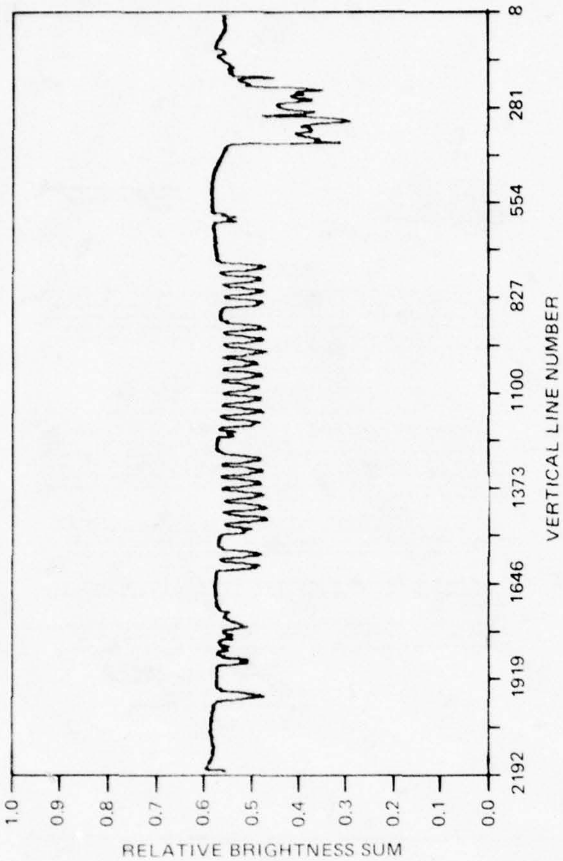
J. Mansfield, Director
Continuing Engineering Education





GWU TYPED PAGE
IMAGE 03-01
8/02/78
BLACK, BEIGE

Figure B8. GWU typed page, Image 03-01.



NUMBER: 768
DATE: 6/17/76

headquarters announcement

SUBJECT: Recycled Paper

As part of our commitment to a better environment and the saving of our vital energy resources, we will be testing recycled bond paper in our copiers and for in-house printing effective the week of June 28, 1976.

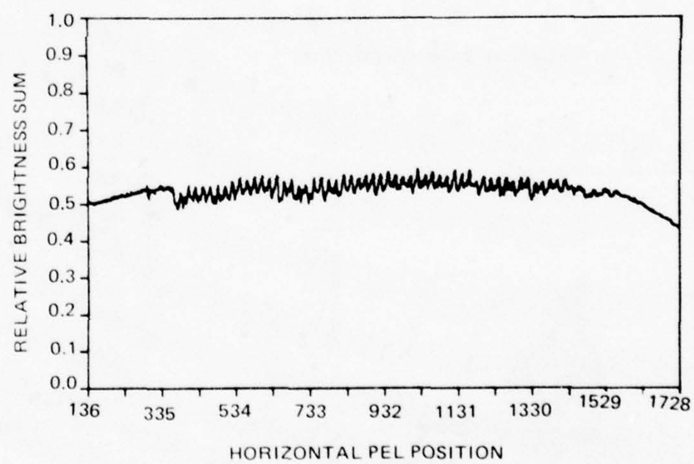
Called recycled bond, the new paper helps solve some of the problems caused in the manufacture of paper. For example, it takes less energy and fewer chemicals to produce recycled bond. As a result, there are fewer waste products to release into the air or dump into our water supply. Also, since recycled bond is made from previously used paper, there is less need to cut down our valuable trees to make new paper pulp. In the present market recycled paper is also more economical.

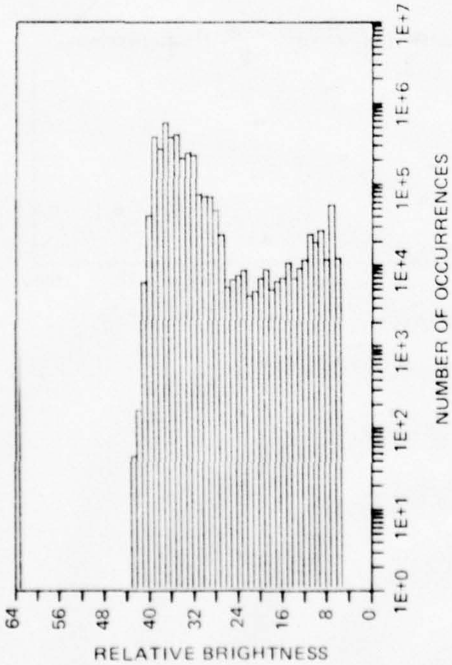
The first thing you will probably notice about recycled bond is its appearance. Rather than bleached white, it is a softer, more natural color and easier on the eyes. The sheets are less likely to curl as they pass through our copiers and duplicators and will cause fewer jamming problems. Recycled bond paper is more opaque with less "show through" for easier reading.

We believe that everyone will be pleased with this worthwhile contribution to a better environment.

Hugh W. Easter
Hugh W. Easter
Director
Office of Headquarters Services

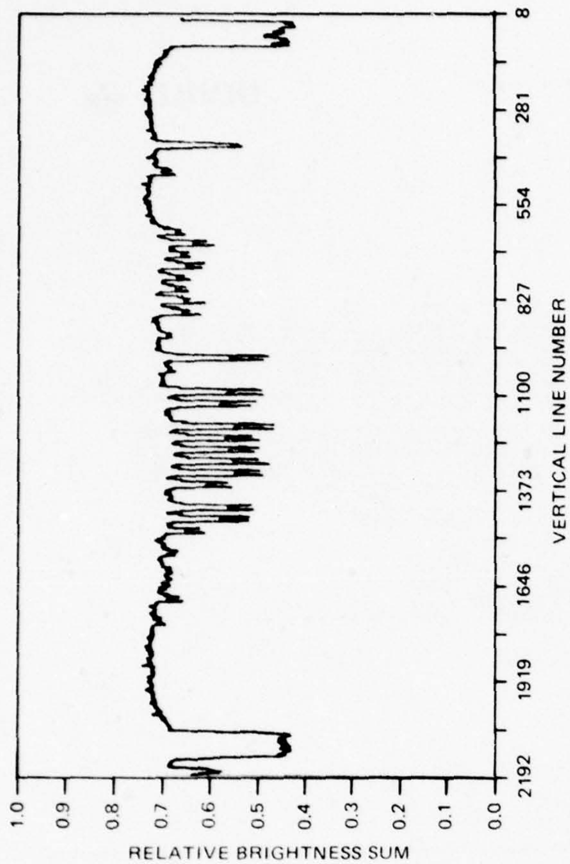
(This is a printed copy made with recycled bond paper)

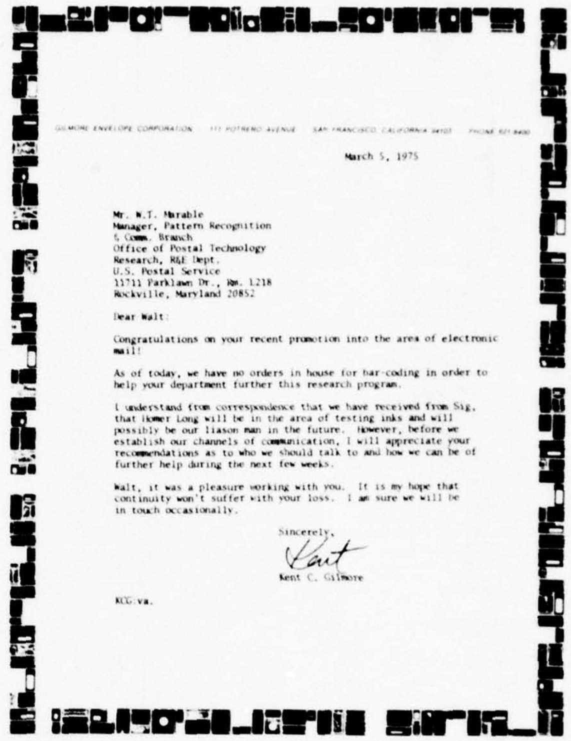




USPS HQ ANNOUNCEMENT
IMAGE 03-02
8/07/78
BLACK, BEIGE

Figure B9. USPS HQ announcement, Image 03-02.





March 5, 1975

Mr. W.T. Marable
Manager, Pattern Recognition
& Comm. Branch
Office of Postal Technology
Research, R&E Dept.
U.S. Postal Service
11711 Parklawn Dr., Rm. 1218
Rockville, Maryland 20852

Dear Walt:

Congratulations on your recent promotion into the area of electronic mail!

As of today, we have no orders in house for bar-coding in order to help your department further this research program.

I understand from correspondence that we have received from Sig, that Homer Long will be in the area of testing inks and will possibly be our liason man in the future. However, before we establish our channels of communication, I will appreciate your recommendations as to who we should talk to and how we can be of further help during the next few weeks.

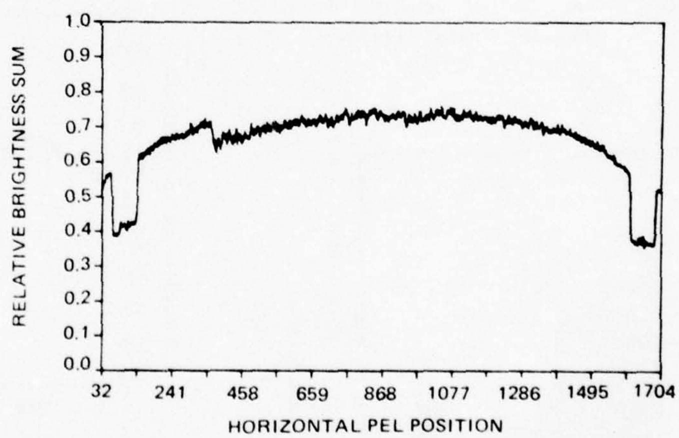
Walt, it was a pleasure working with you. It is my hope that continuity won't suffer with your loss. I am sure we will be in touch occasionally.

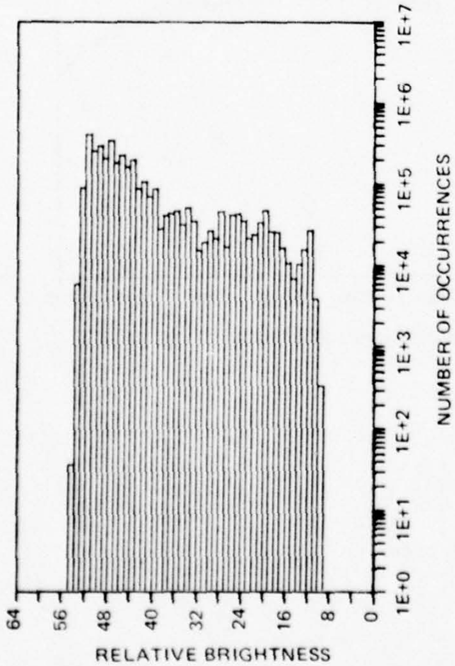
Sincerely,

Kent

Kent C. Gilmore

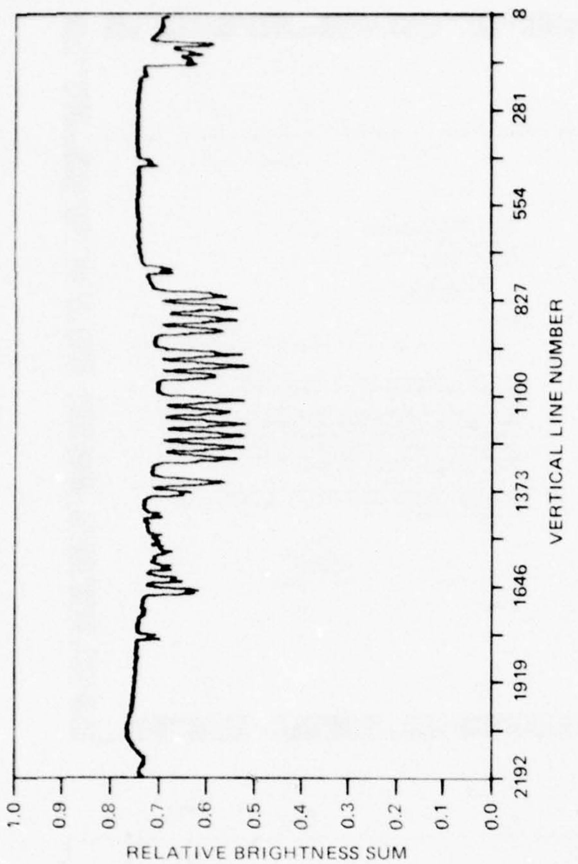
KCG:va.





WTM TYPED PAGE
IMAGE 04-01
8/02/78
BLACK, WHITE, BLUE SIGNATURE,
MULTI-COLORED BORDER

Figure B10. WTM typed page, Image 04-01.



GOULD

16 June 1978

Dear '78 NCC Visitor:

Thank you for stopping at the Gould booth in Anaheim. Gould Electrostatic Printer/Plotters provide high quality, high speed, and high resolution hard copy with excellent reliability and we appreciate the opportunity to show you our products.

Enclosed is the information you requested. Should you have any further questions, please contact our nearest sales representative whose telephone number is on the enclosed list.

Our sales representatives will be glad to meet with you to discuss your specific application, show you plot or print samples, and demonstrate equipment. In addition, our representatives are prepared to discuss the various system configurations and alternatives as well as the various lease/purchase and service plans available from Gould to satisfy your hard copy requirements.

Again, thank you for taking the time to stop at our booth. We look forward to hearing from you.

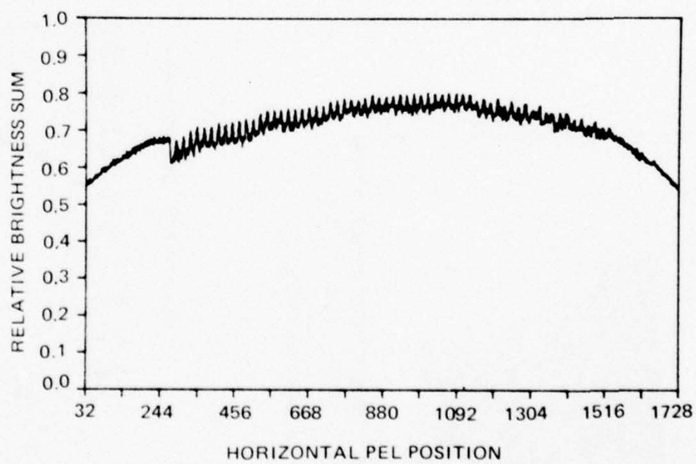
Sincerely,

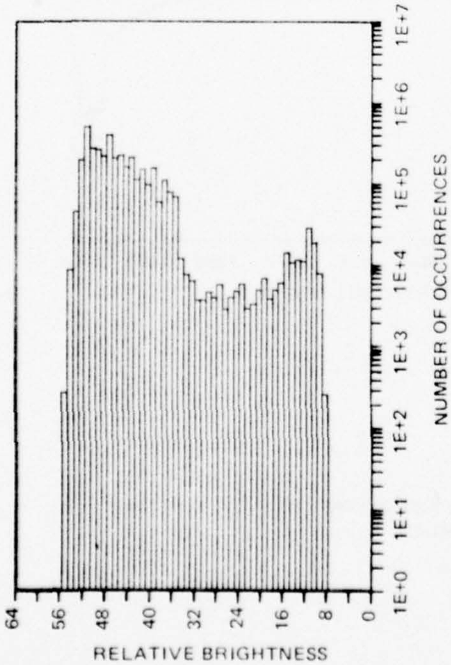
John Staggs

John F. Staggs
National Sales Manager
Electrostatic Printer/Plotter Products

/ld

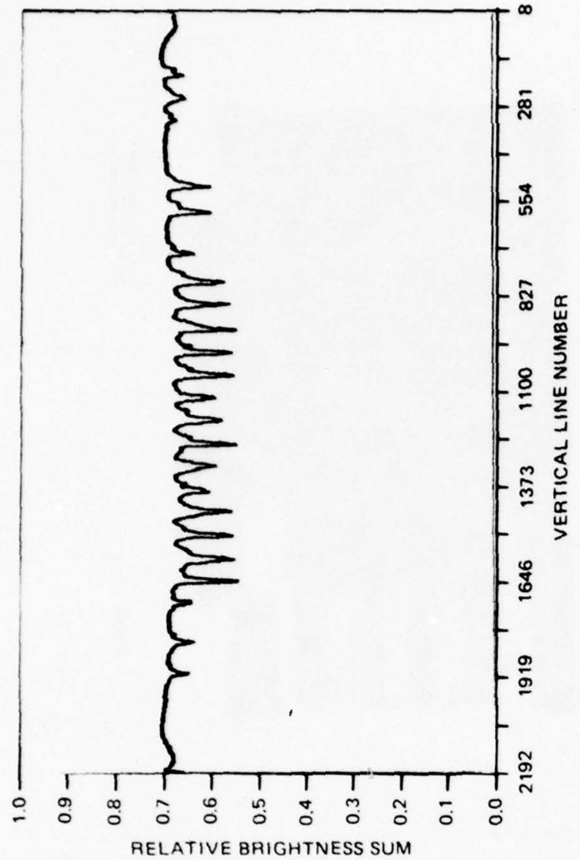
Enclosures

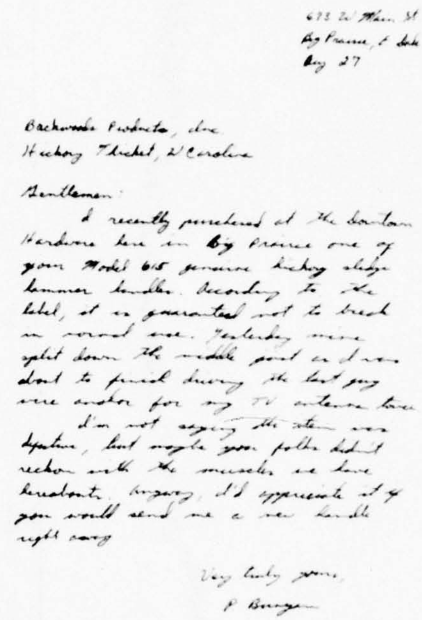




GOULD TYPED PAGE
IMAGE 04-02
8/07/78
BLACK, WHITE, BLUE LOGO

Figure B11. Gould typed page, Image 04-02.





673 W. Main St
Big Prairie, S. Dak.
Aug 27

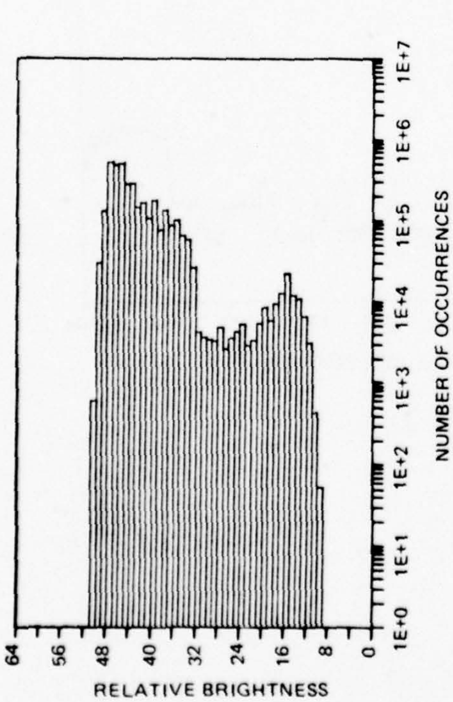
Backwoods Products, Inc.
Hickory Thicket, N. Carolina

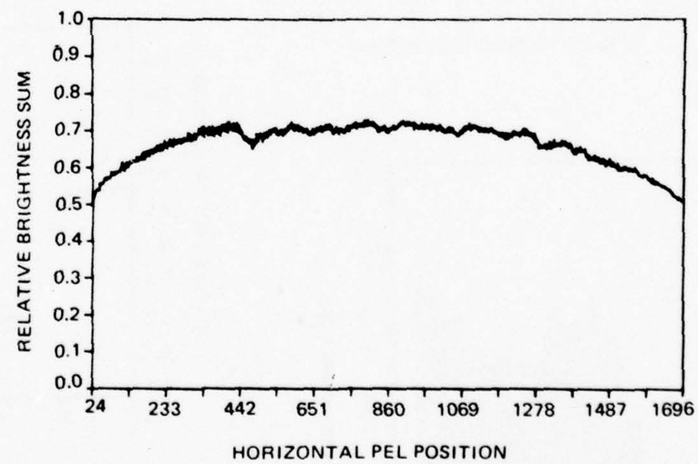
Gentlemen:

I recently purchased at the Downtown Hardware here in Big Prairie one of your Model 615 genuine hickory sledge hammer handles. According to the label, it is guaranteed not to break in normal use. Yesterday mine split down the middle just as I was about to finish driving the last guy wire anchor for my TV antenna tower.

I'm not saying the item was defective, but maybe your folks didn't reckon with the muscles we have hereabouts. Anyway, I'd appreciate it if you would send me a new handle right away.

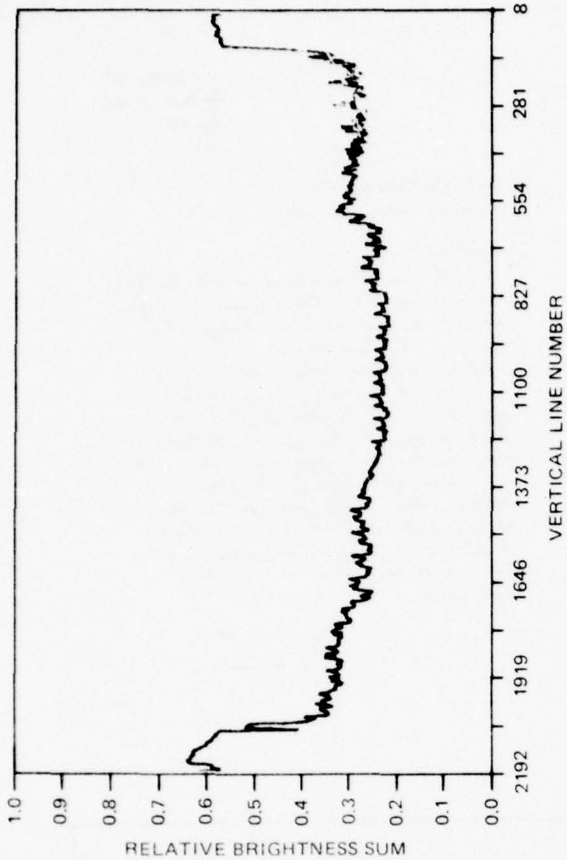
Very truly yours,
P Bunyan

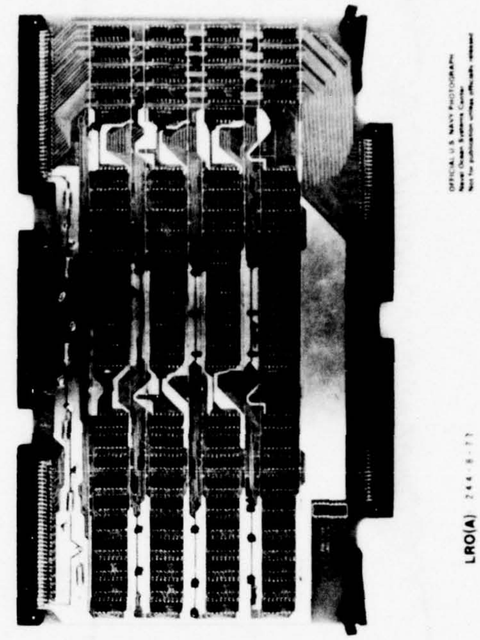


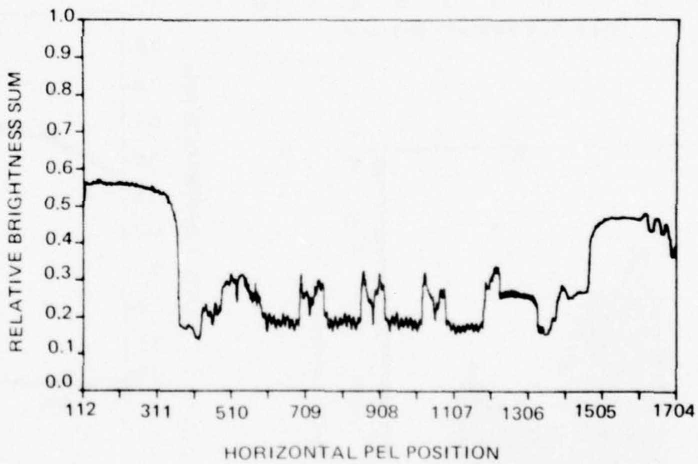


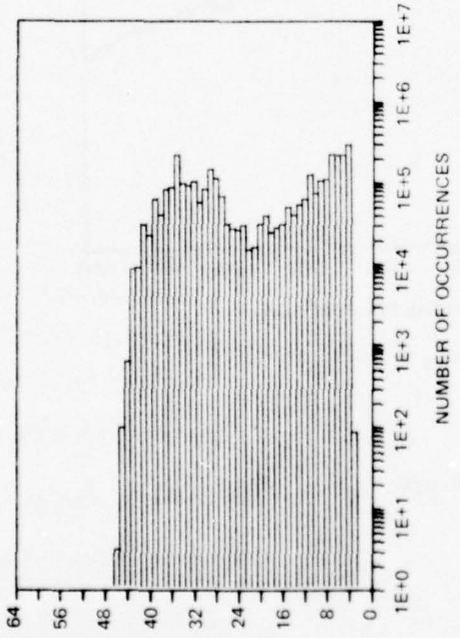
PAUL BUNYAN LETTER - PEN
IMAGE 06-01
8/02/78
BLUE, WHITE

Figure B12. Paul Bunyan letter - pen, Image 06-01.









MIC CARD
IMAGE 11-01
8/02/78
BLACK, WHITE

Figure B13. MIC card (photograph), Image 11-01.

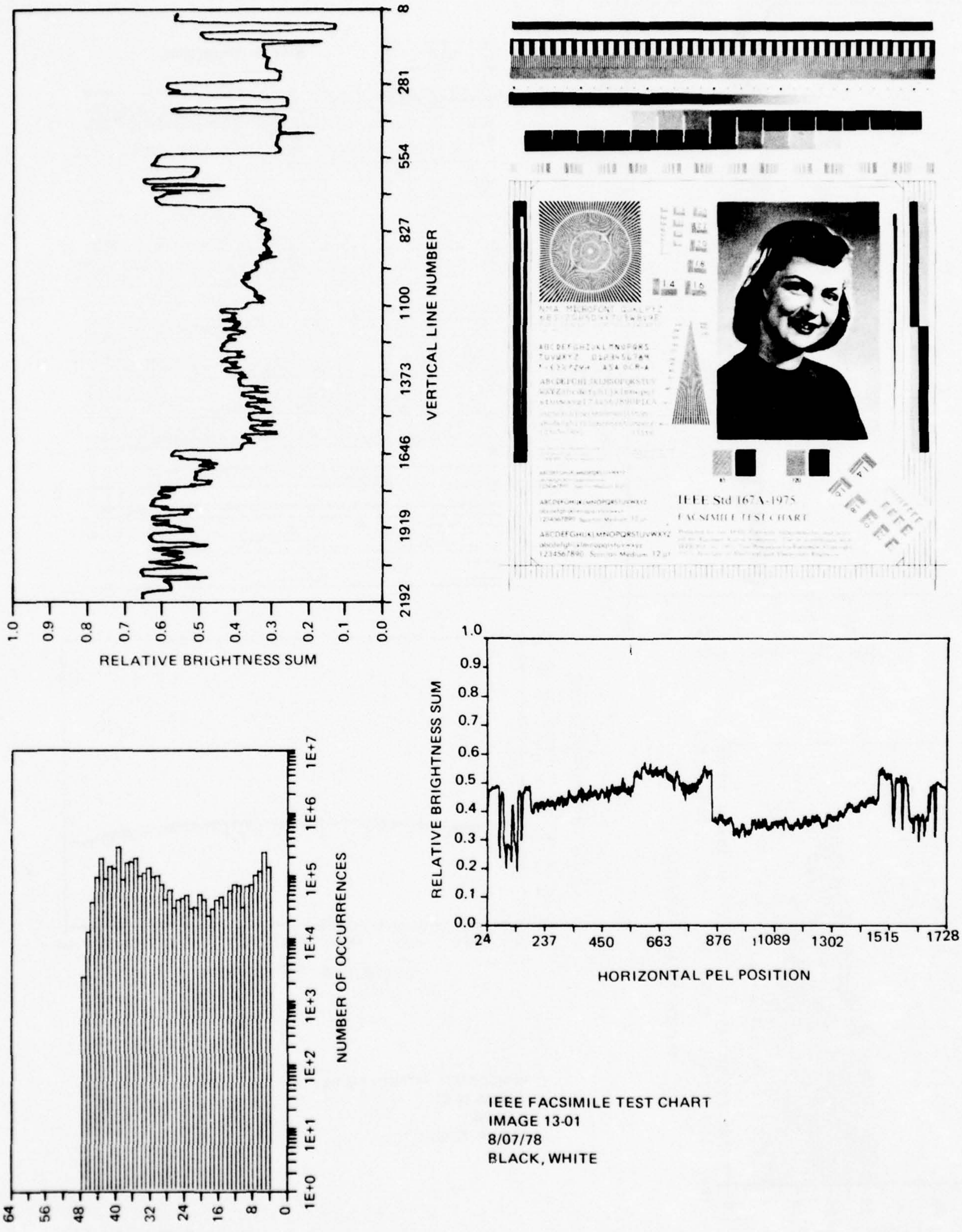
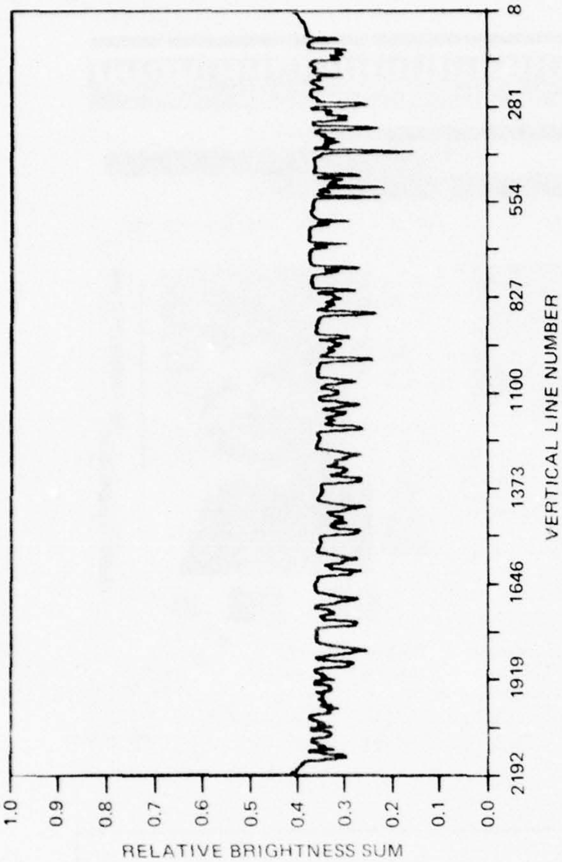
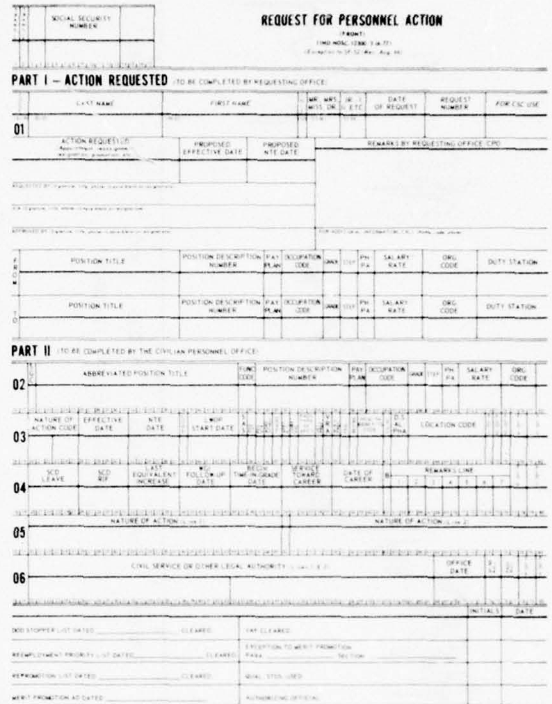
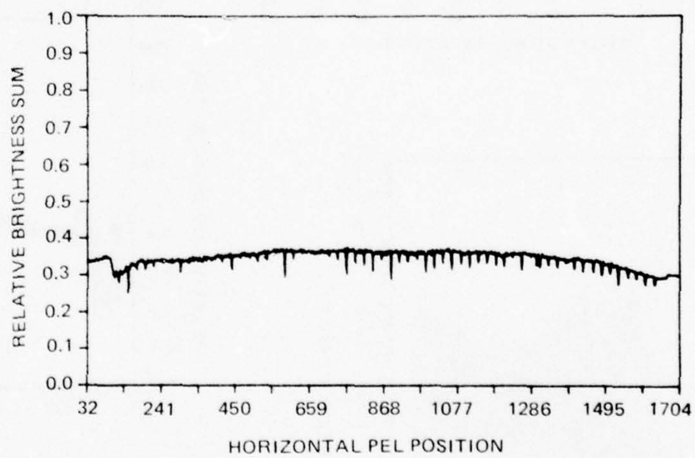
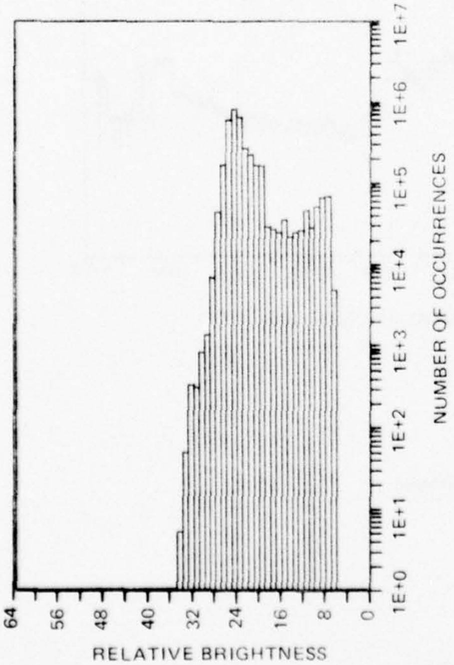


Figure B14. IEEE facsimile test chart, Image 13-01.









PERSONNEL ACTION FORM
IMAGE 14-01
8/02/78
BLACK, GREEN

Figure B15. Personnel action form, Image 14-01.

This image is a good candidate for thresholding since there is no evidence of continuous-tone imagery due to the regularity of the SFI responses. A document of this type would not be a candidate for OCR scanning. The same comments may be applied to figure B16.

Figure B17 is an image made on the Versatec Electrostatic Plotter. This form shows a good deal of regularity in the SFI but does not provide the usual typed page profile in the PBS histogram because of the fine resolution of the imagery. Therefore, this document would be classified to be scanned at full PBS amplitude resolution.

Figure B18 is a full-page Newsweek advertisement which contains black, yellow, and red ink on white paper. This image passes essentially none of the three criteria for thresholding or submission for OCR and therefore would be scanned at full resolution.

Figures B19 through B26 contain a series of interesting results obtained from a set of test documents prepared by Fairchild Imaging Systems in Syosset, New York. One of the objectives in preparing the test document set was to produce a wide range of samples having varying print contrast ratios (PCRs). This entailed having a series of white bond pages on which the reflection density of the ink gradually increased, thus reducing the PCR. This portion of the document set was produced by a printing company which prepared an offset master and ran a series of pages with a gradually decreasing ink supply so that the typed data became increasingly fainter. The pages were identified by a sequence number, and the reflection density of the ink and bond paper at intervals throughout the deck was determined. Four hundred equally spaced samples in the range from maximum to 0.3 PCR were selected. The document number appears at the bottom left corner of each document. Documents shown in this series are numbers 0(148), 0(456), 0(820), and 0(1208). The PCRs of these images are 0.788, 0.674, 0.514, 0.152, respectively.

Two sets of data are shown for each of these four images. Each of the four images was acquired only once. One of the sets of SFI data and PBS represents data from the uncorrected image. The second version of each of the four images relates to data which have been through the process of illumination correction.

Figures B19 and B20 represent the uncorrected and corrected data, respectively, for image number 0(148). This is the page which has the darkest ink impression and therefore the highest response in vertical and horizontal SFIs of the document series shown here. These two features may be observed to decrease measurably through the set of four samples shown. The PBS histogram extends down to approximately level 8 because of the adequate supply of ink, and the SFI curves show much activity and contrast. The differences between figures B19 and B20 insofar as SFI_v is concerned are almost negligible. The SFI_h curve shows that the brightness response across the page has indeed flattened. The PBS histograms, however, appear quite different. There is a rather jagged appearance to the histograms for the uncorrected image. Figure B20, however, shows an almost classical PBS response for a typed page. The brightness of the substrate is grouped very concisely around level 51, and the saddle of the curve leading to the major response of the ink at level 12 is quite uniform.

Much of the dispersion of the PBS in figure B19 is due to the distribution of brightness response across both the ink and the substrate with non-illumination-corrected images.

The pairs of images (figures B21 and B22) which pertain to image 0(456) still produce vertical and horizontal SFI and PBS histograms which would cause acceptance for bilevel scanning and presentation to OCR equipment.

Figures B23 and B24 are the pair of results for image 0(820). In observing the PBS in figure B24, it is of interest to note that the reflectance of the ink is now clustered around level 23. The other response shown at around levels 9 and 10 is the result of the document numbering system which is shown at the lower left portion of the original image. In the four

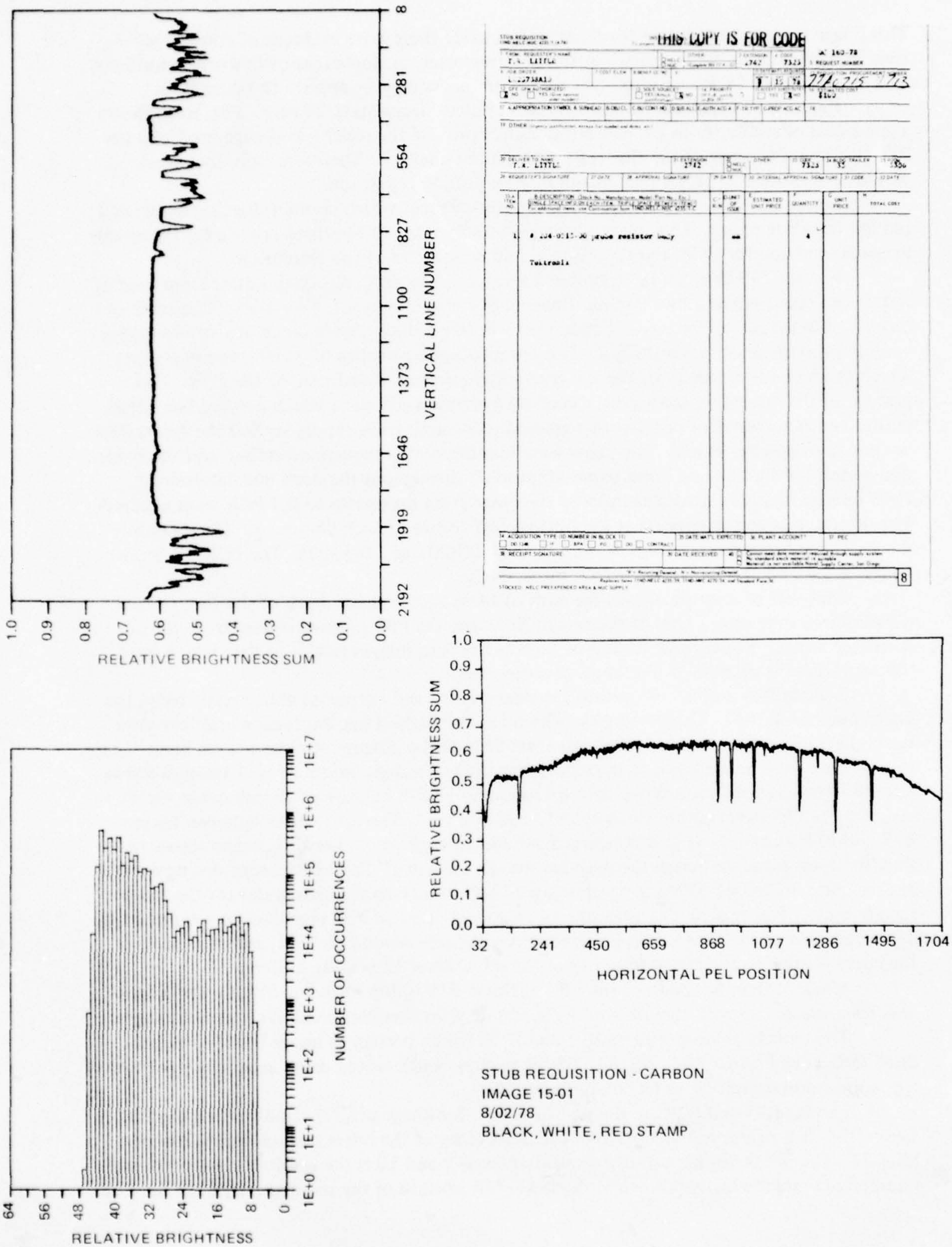
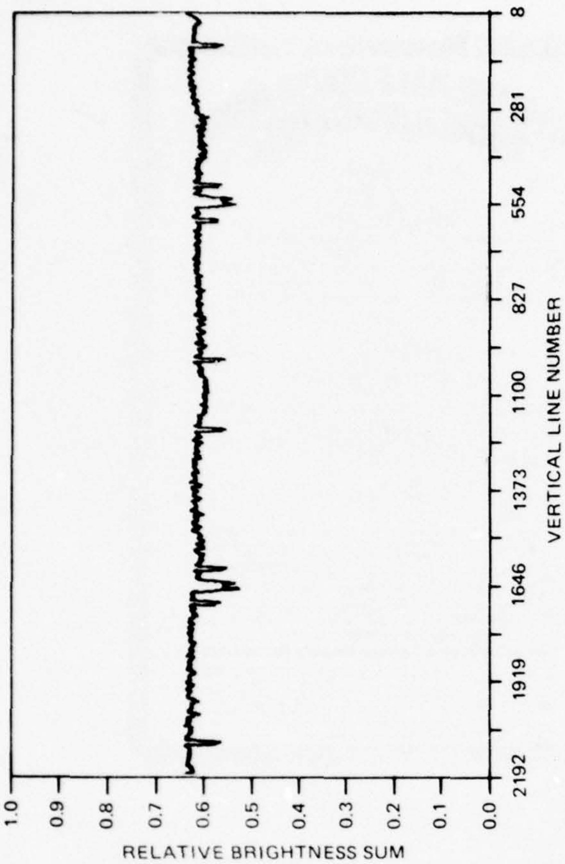
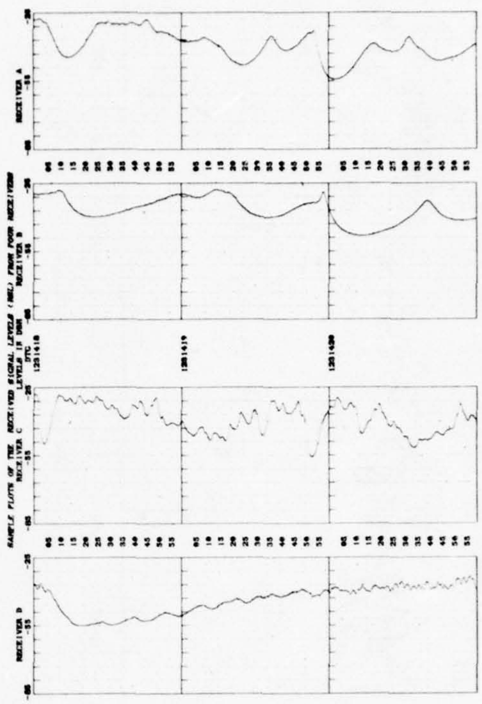
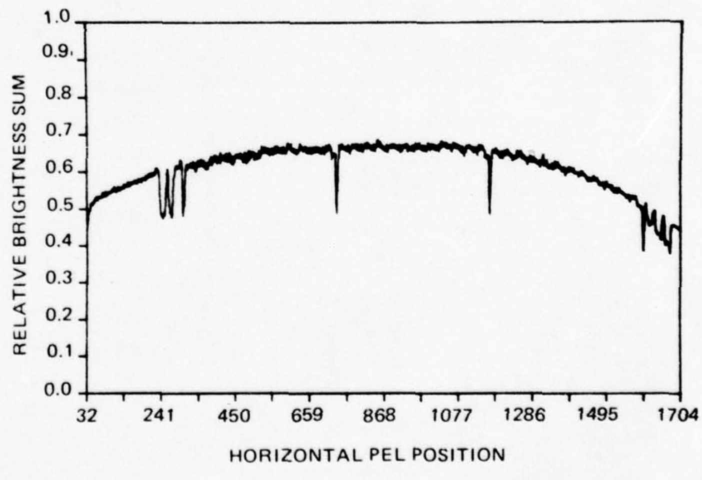
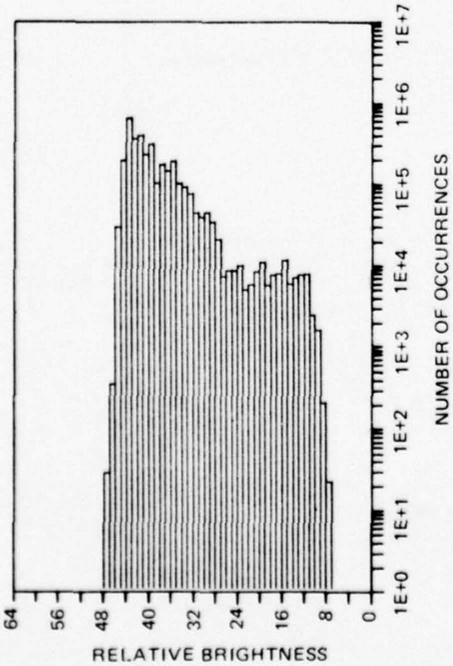


Figure B16. Stub requisition carbon, Image 15-01.



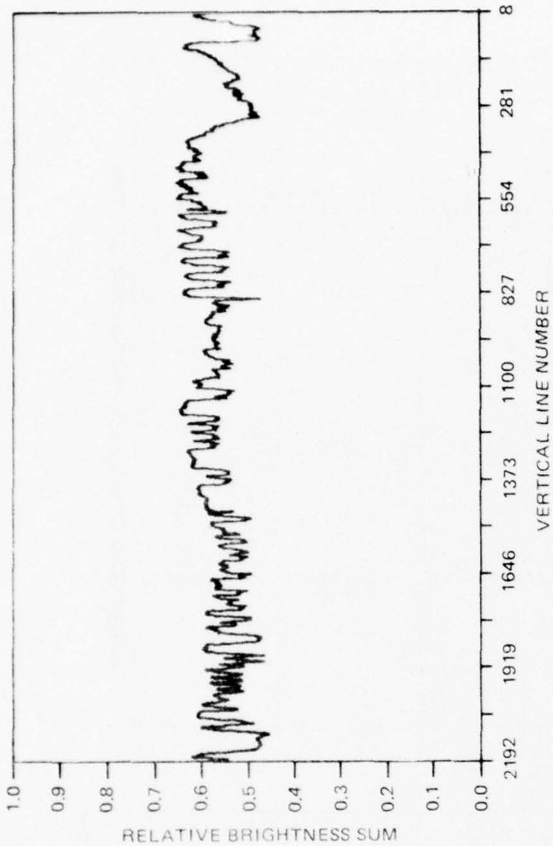


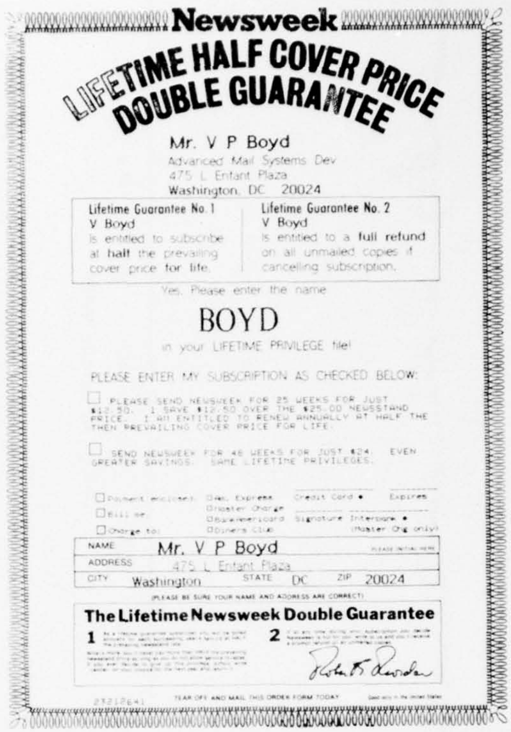


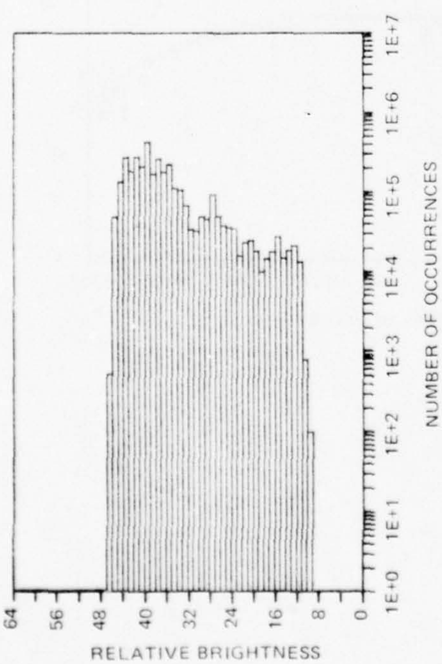


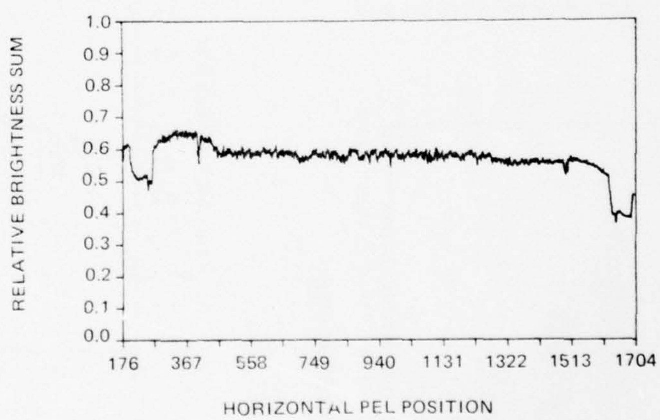
VERSATEC PLOT
IMAGE 16-01
8/02/78
BLACK, WHITE

Figure B17. Versatec plot, Image 16-01.



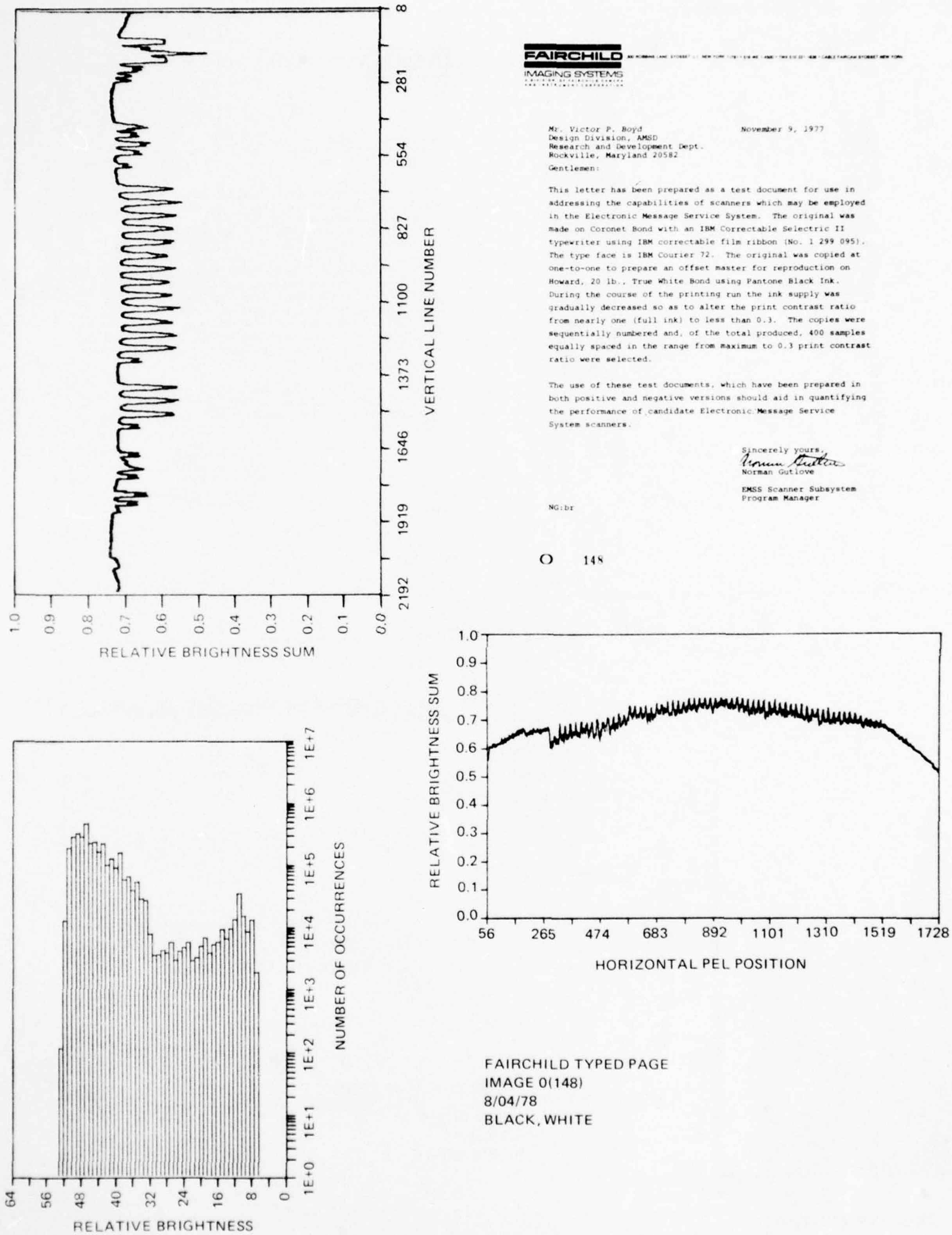






NEWSWEEK AD
IMAGE 17-01
8/02/78
BLACK, WHITE, YELLOW, RED

Figure B18. Newsweek advertisement, Image 17-01.



FAIRCHILD
IMAGING SYSTEMS

Mr. Victor P. Boyd
Design Division, AMSD
Research and Development Dept.
Rockville, Maryland 20582

November 9, 1977

Gentlemen:

This letter has been prepared as a test document for use in addressing the capabilities of scanners which may be employed in the Electronic Message Service System. The original was made on Coronet Bond with an IBM Correctable Selectric II typewriter using IBM correctable film ribbon (No. 1 299 095). The type face is IBM Courier 72. The original was copied at one-to-one to prepare an offset master for reproduction on Howard, 20 lb., True White Bond using Pantone Black Ink. During the course of the printing run the ink supply was gradually decreased so as to alter the print contrast ratio from nearly one (full ink) to less than 0.3. The copies were sequentially numbered and, of the total produced, 400 samples equally spaced in the range from maximum to 0.3 print contrast ratio were selected.

The use of these test documents, which have been prepared in both positive and negative versions should aid in quantifying the performance of candidate Electronic Message Service System scanners.

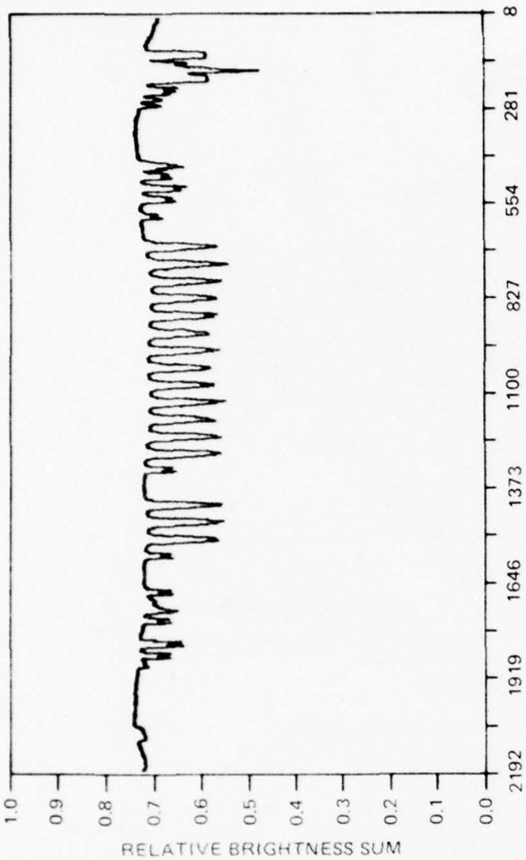
Sincerely yours,
Norman Gutlove

EMSS Scanner Subsystem
Program Manager

NG:br

O 148

Figure B19. Fairchild typed page, uncorrected Image 0(148).



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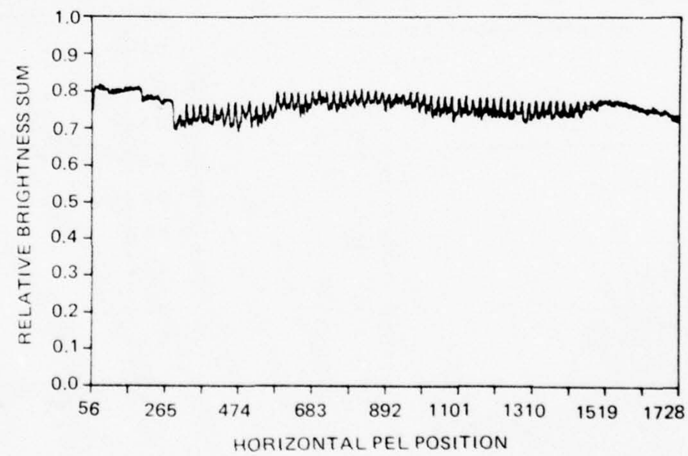
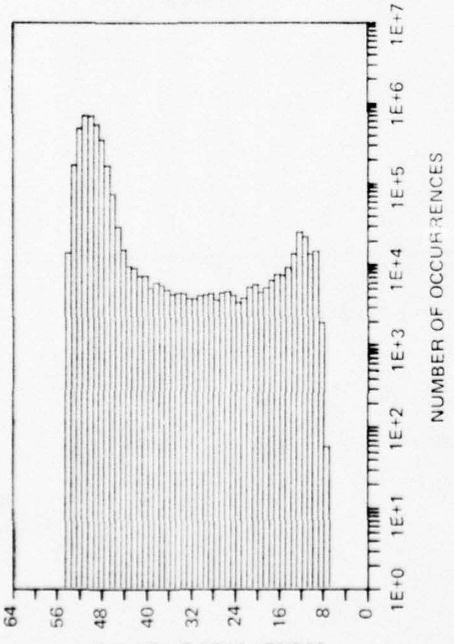
Norman Gutlove

EMSS Scanner Subsystem
Program Manager

NG:br

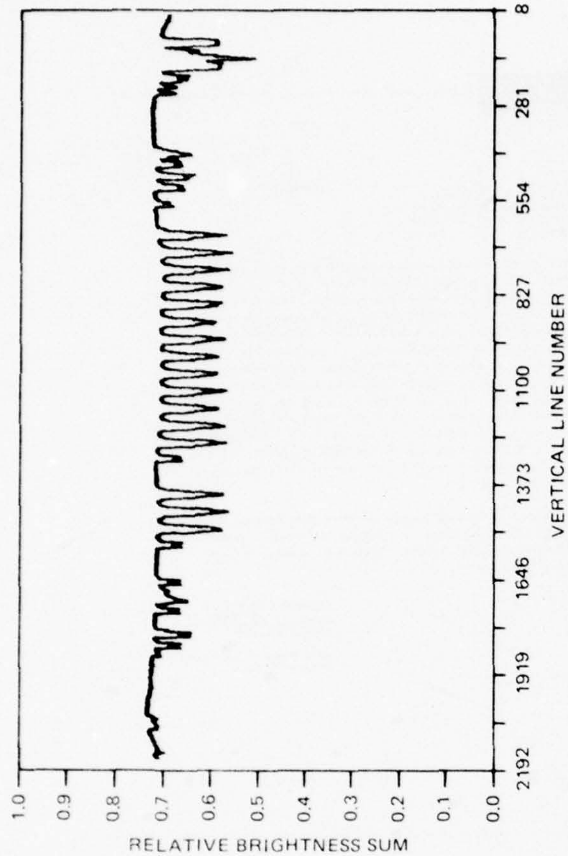
O 148





FAIRCHILD TYPED PAGE
ILLUMINATION CORRECTED
IMAGE 0(148)
8/04/78
BLACK, WHITE

Figure B20. Fairchild typed page, corrected Image 0(148).



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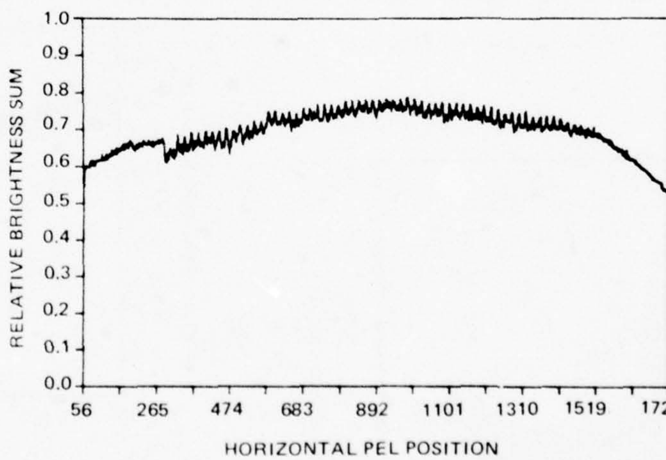
Sincerely yours,

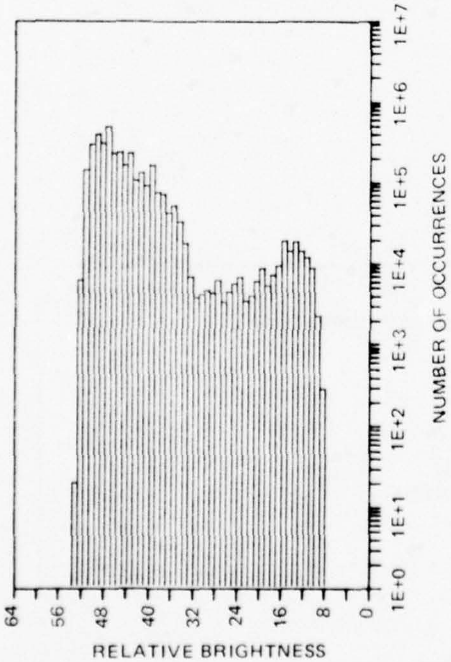
Norman Gutlove

EMSS Scanner Subsystem
Program Manager

NG:br

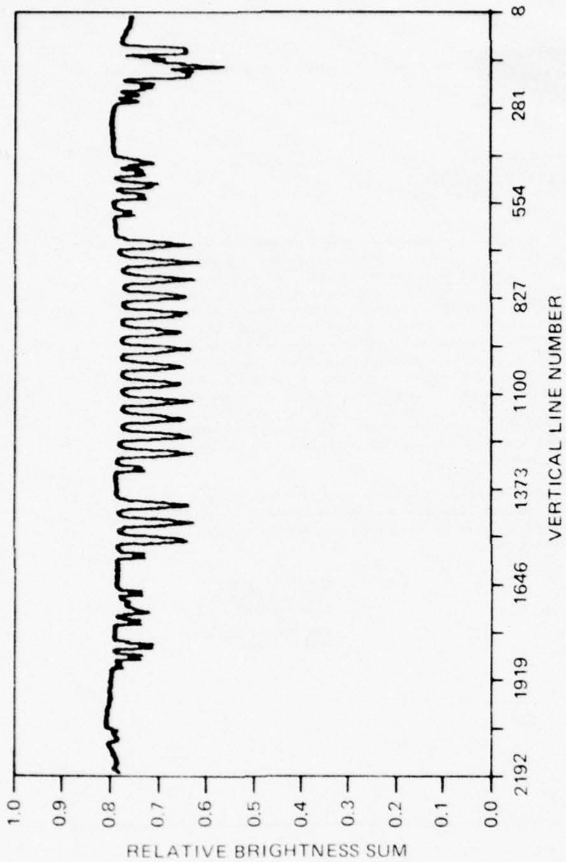
O 456

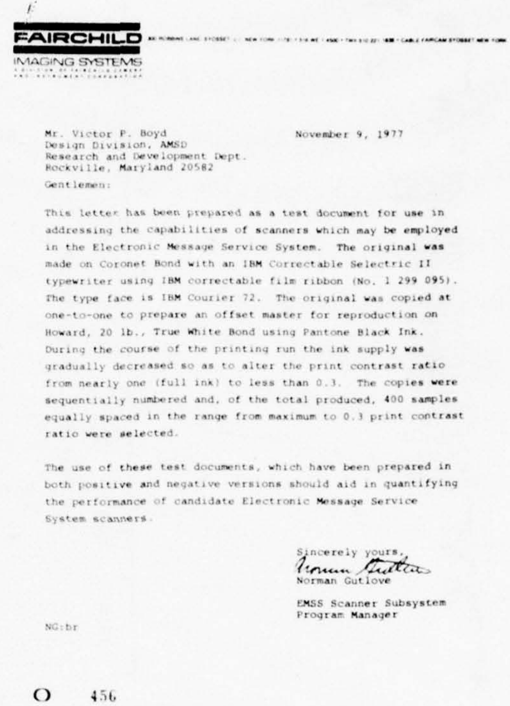




FAIRCHILD TYPED PAGE
IMAGE 0(456)
8/04/78
BLACK, WHITE

Figure B21. Fairchild typed page, uncorrected Image 0(456).





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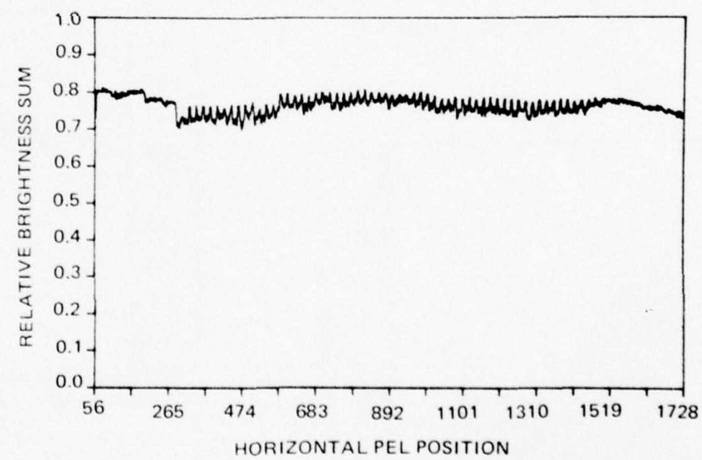
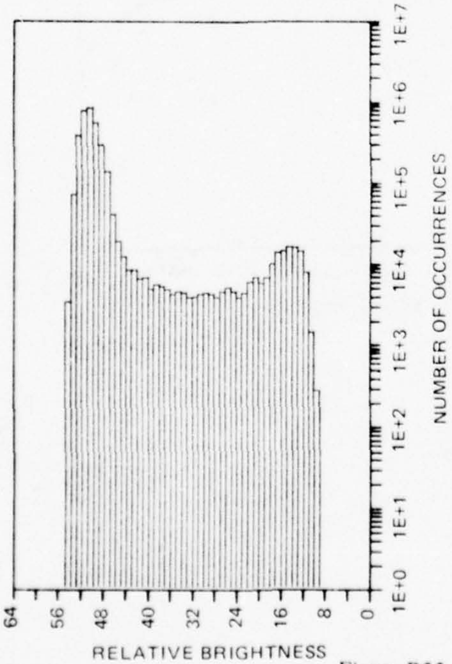
Norman Gutlove

EMSS Scanner Subsystem
Program Manager

NG:br

O 456





FAIRCHILD TYPED PAGE
ILLUMINATION CORRECTED
IMAGE 0(456)
8/04/78
BLACK, WHITE

Figure B22. Fairchild typed page, corrected Image 0(456).

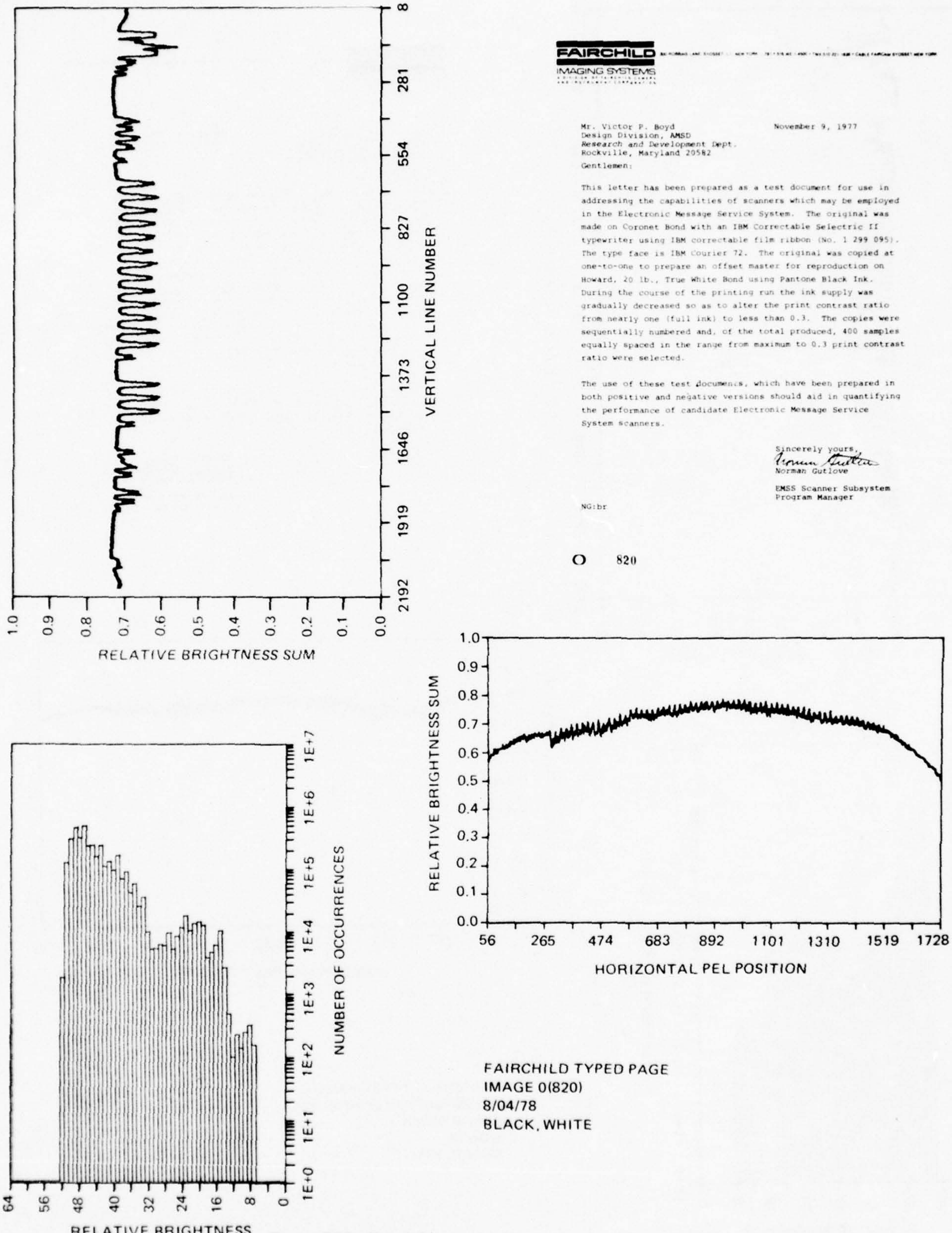
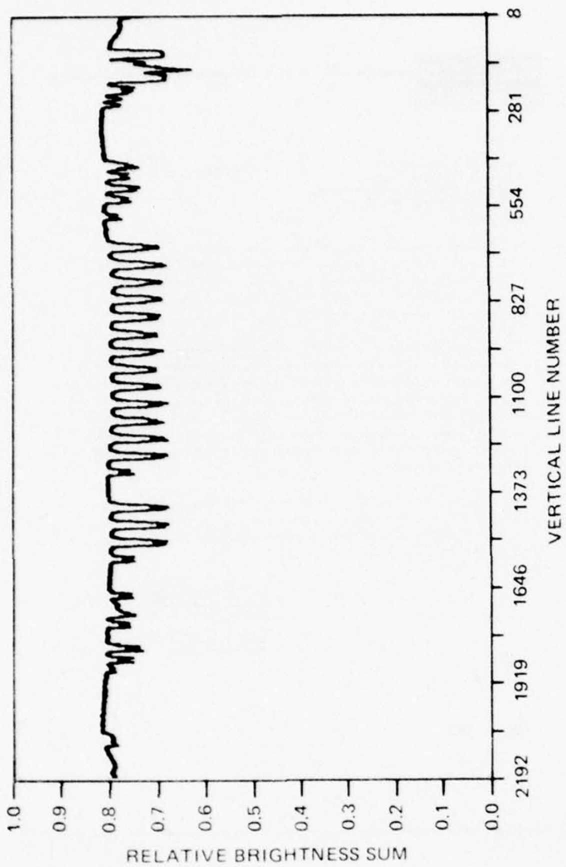
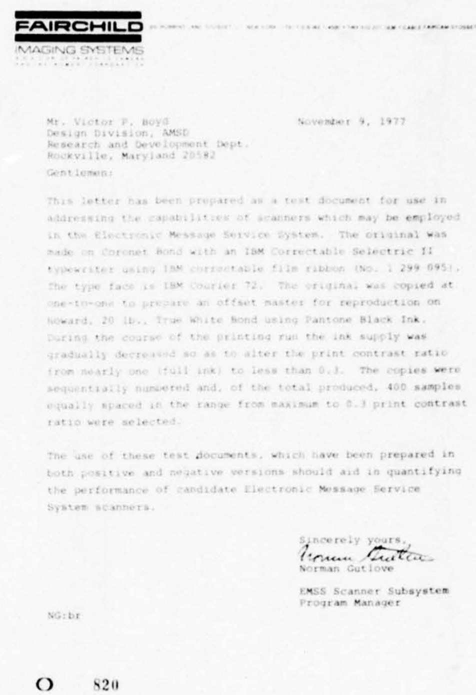


Figure B23. Fairchild typed page, uncorrected Image 0(820).





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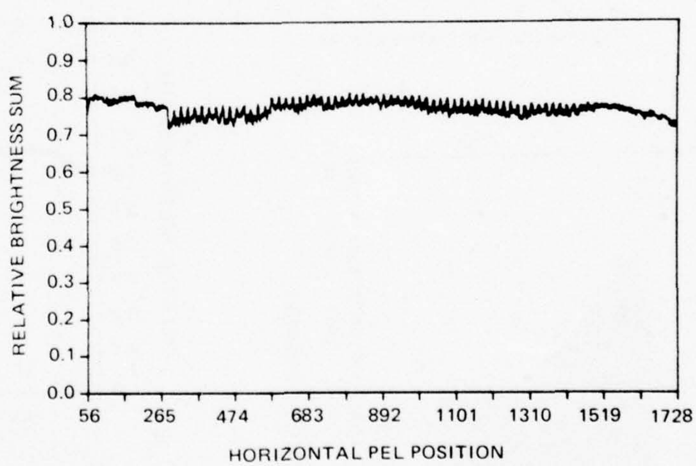
Sincerely yours,

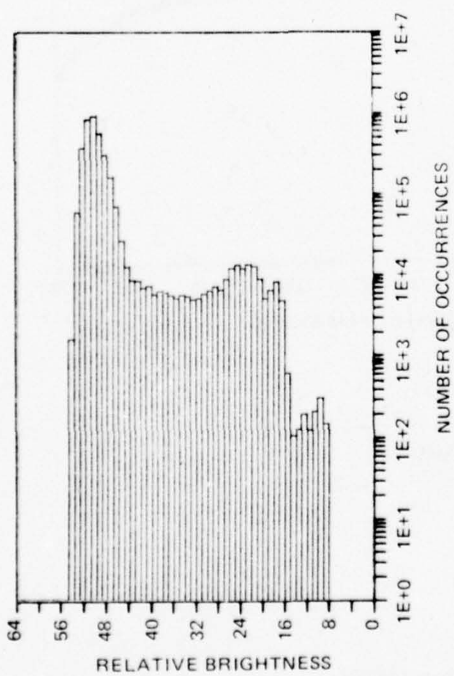
Norman Gutlove

EMSS Scanner Subsystem
Program Manager

NG:br

O 820





FAIRCHILD TYPED PAGE
ILLUMINATION CORRECTED
IMAGE 0(820)
8/04/78
BLACK, WHITE

Figure B24. Fairchild typed page, corrected Image 0(820).

characters "0(820)" there is enough ink at high absorption blackness (since this was put on with a fully inked stamp) to cause response shown at the lower brightness levels in the PBS.

The last pair of figures, B25 and B26, are for document 0(1208). In figure B25 there still exists sufficient component of SFI_v to allow classification of the document as probably typing. The SFI_h, however, does not contain a significant amount of evidence that the page contains typing. Also, the PBS histogram shows a confusing bias which might be mistakenly interpreted as the substrate background (levels 32 to 51) and the ink at ground level 8 or 9.

By looking at figure B26, the PBS can be correctly interpreted. The ink reflectance level is approximately 37 and the substrate brightness level is approximately 49. The peak at approximately level 9 is due to the overimpression of the serial number of the document 0(1208).

It can be seen that illumination correction appreciably improves the chances of properly interpreting the PBS by providing more uniform response from the substrate and the ink. Because of the lack of an SFI component of adequate amplitude and the confusing double hump in the pel brightness histogram, this image would probably not be detected as a bilevel image for presentation to the OCR equipment.

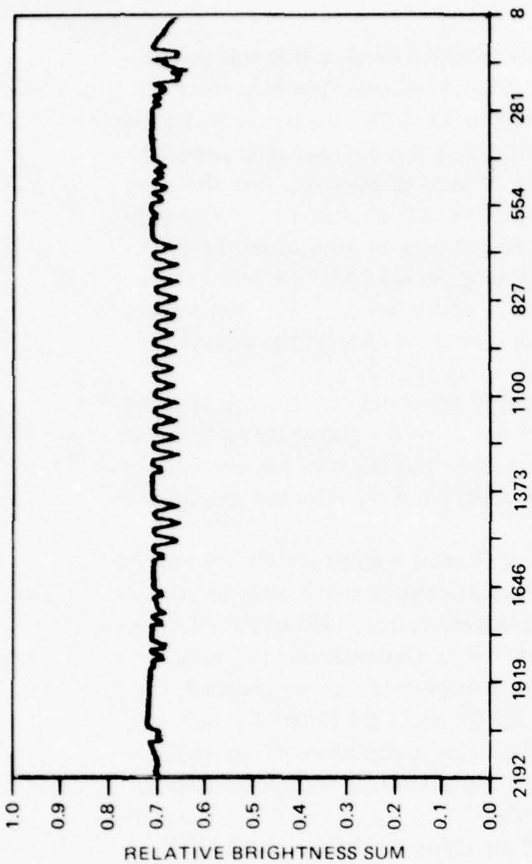
The results of the preceding discussion indicate that there is a good possibility that certain classification features already included in the analysis are strong candidates to provide a decision process as to the nature of the document under consideration. SFI in the horizontal direction (across a page) indicates typing when there are 10 or 12 characters per inch, which results in 20 or 16.67 pels per character. At 21 megapels per second per channel, the horizontal spatial frequency component lies between 4.2×10^6 and 5.04×10^6 characters per second. A simple filter identifying the presence of SFI_h at or approximately around these frequencies should indicate that the document is a strong candidate for bilevel acquisition and a candidate for potential OCR character recognition.

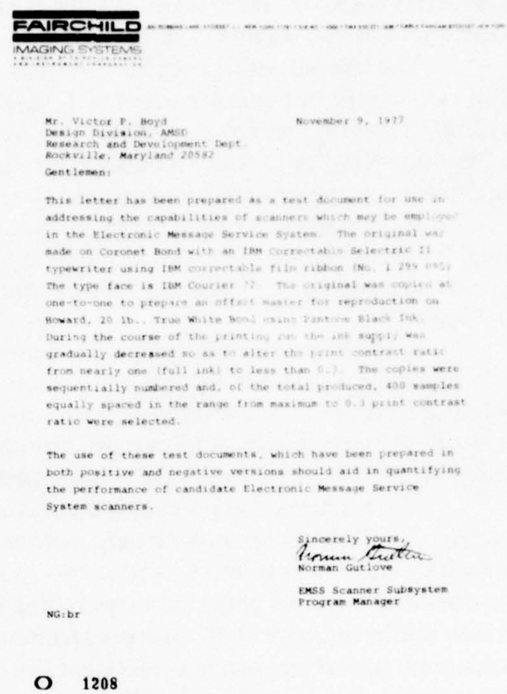
The spatial frequency identification in the vertical direction can be detected by examining sums of rows of data. The approximately six lines per inch in an IBM Selectric Typewriter equates to approximately 33.3 lines per character; or, at a maximum rate of 20 pages per second, the rate of the SFI_v signal is approximately 1.44×10^3 characters per second.

The third parameter for attempting to categorize typed pages is the PBS histogram. There are a considerable number of characteristics pertaining to the PBS histogram which provide the necessary clues indicating the presence of bilevel information. The very nature of bilevel information indicates that the data in the histogram should lie primarily in two brightness zones. These brightness zones on the histogram will be more pronounced if the data are illumination corrected or essentially flat field illumination is provided as the document is originally scanned. Also, in the absence of large logos the brightest of the two peaks of bilevel data will normally be the substrate (unless white ink is used on a dark substrate). One would expect the ratio of substrate to ink to be roughly 25 to 1, since the ink on image numbers 02-01 and 02-02 constitutes 4% of the total page area.

Third, the pel brightness histogram should include a saddle point between the two statistical entities representing the substrate and the ink. The depth of the excursion below a tangent drawn across the two peaks to the saddle point is an indication of the cumulative linear quantity of edges shown in the image. In other words, this represents pels which included both portions of typing as well as substrate, providing a total integrated value lying somewhere between the two bilevel brightness levels.

Some thought has been given to an automatic algorithm for the classification of the pel brightness histogram into a go/no-go indicator for bilevel imagery. As yet this algorithm has not been reduced to practice, but it soon will be tested against images in the data base.





FAIRCHILD
IMAGING SYSTEMS

Mr. Victor P. Boyd
Design Division, AMSD
Research and Development Dept.
Rockville, Maryland 20582

November 9, 1977

Gentlemen:

This letter has been prepared as a test document for use in addressing the capabilities of scanners which may be employed in the Electronic Message Service System. The original was made on Coronet Bond with an IBM Correctable Selectric II typewriter using IBM correctable film ribbon (No. 1 299 095). The type face is IBM Courier 72. The original was copied at one-to-one to prepare an offset master for reproduction on Howard, 20 lb., True White Bond using Pantone Black Ink. During the course of the printing run the ink supply was gradually decreased so as to alter the print contrast ratio from nearly one (full ink) to less than 0.3. The copies were sequentially numbered and, of the total produced, 400 samples equally spaced in the range from maximum to 0.3 print contrast ratio were selected.

The use of these test documents, which have been prepared in both positive and negative versions should aid in quantifying the performance of candidate Electronic Message Service System scanners.

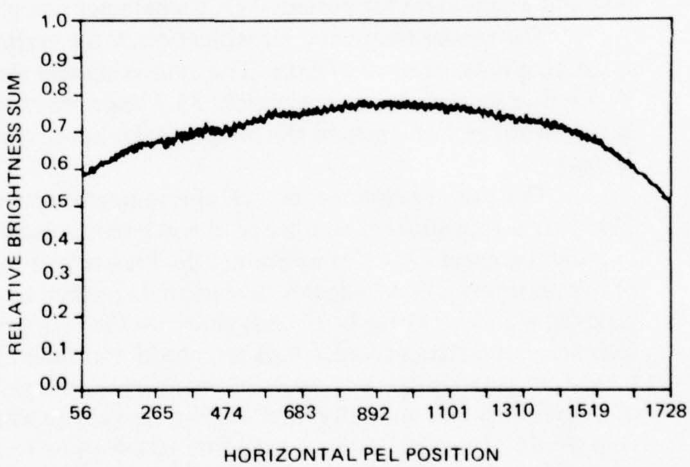
Sincerely yours,

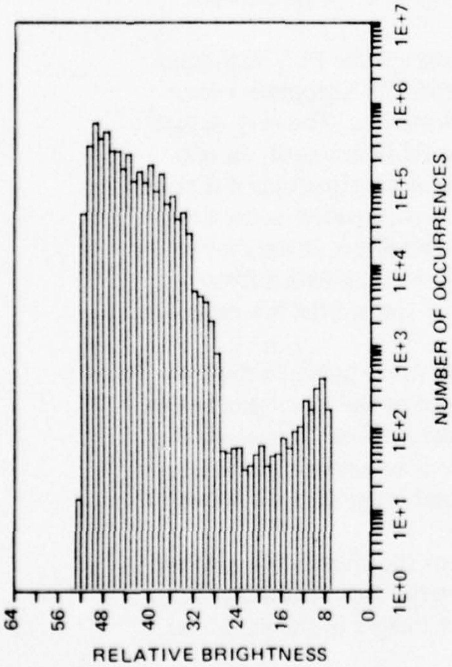
Norman Gutlove

EMSS Scanner Subsystem
Program Manager

NG:br

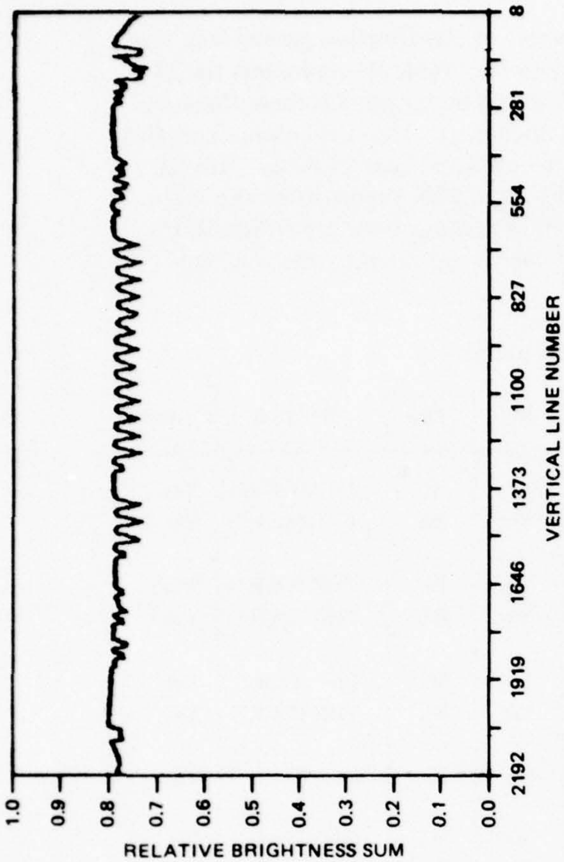
O 1208

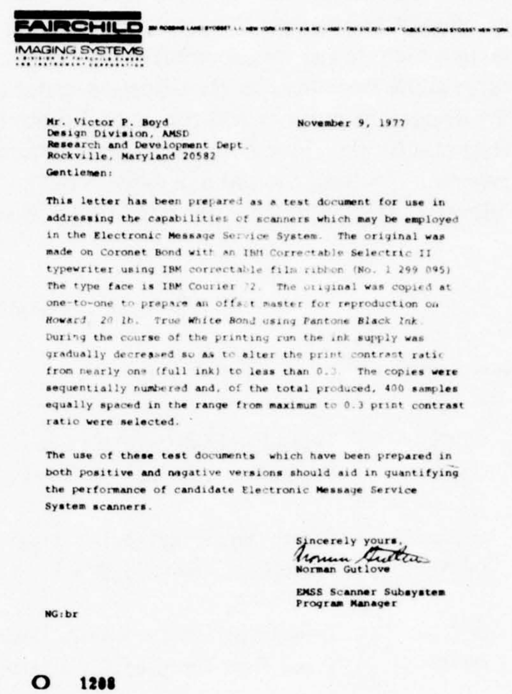




FAIRCHILD TYPED PAGE
IMAGE 0(1208)
8/04/78
BLACK, WHITE

Figure B25. Fairchild typed page, uncorrected Image 0(1208).





FAIRCHILD
IMAGING SYSTEMS

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The use of these test documents which have been prepared in both positive and negative versions should aid in quantifying the performance of candidate Electronic Message Service System scanners.

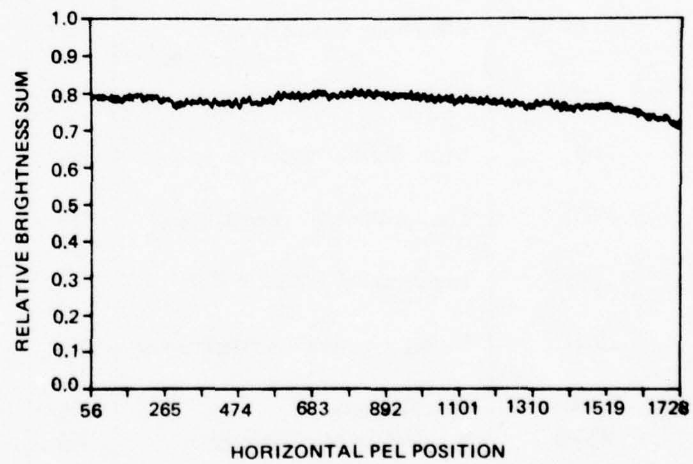
Sincerely yours,

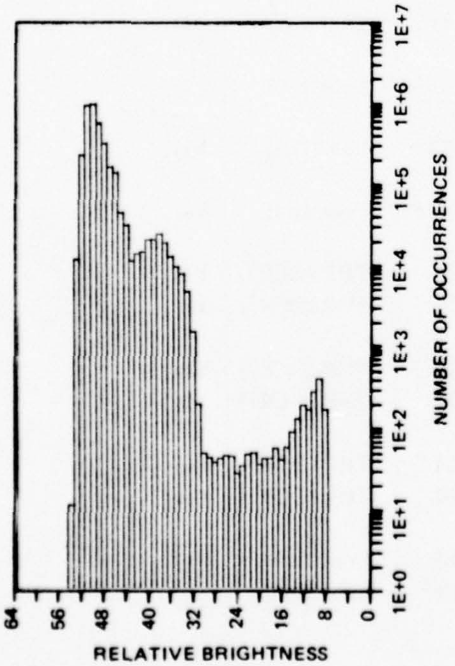
Norman Gutlove

EMSS Scanner Subsystem
Program Manager

NG:br

O 1208





FAIRCHILD TYPED PAGE
ILLUMINATION CORRECTED
IMAGE 0(1208)
8/04/78
BLACK, WHITE

Figure B26. Fairchild typed page, corrected Image 0(1208).

Given that the two SFIs and the PBS form a subset of classification parameters, it is of interest to tabulate the results of the data analysis thus far. Table B1 represents the 21 images included in this appendix and the results which would be achieved if these three features alone were used as classification criteria for each document. The first column contains the document number and the next column indicates the class and type of image. This is followed by the three columns of parameters, SFI_v, SFI_h, and PBS, representing the three parameters voting toward a decision. In the PBS column, the indications are either BL for bilevel or ML for multilevel, indicating which type of image is indicated by the resulting

Table B1. Imagery analysis summary.

Document No	Class & Type	SFI_v	SFI_h	PBS	Decision	Correct
02-01	Typed Page, Unsigned, No Logo	Yes	Yes	BL	THR (OCR?)	Yes
02-02	Typed Page, Unsigned, No Logo	Yes	Yes	BL	THR (OCR?)	Yes
03-01	Typed Page, Unsigned, B/W Logo	Yes	Yes	BL	THR (OCR?)	Yes
03-02	Typed Page, Unsigned, B/W Logo	Yes	Yes	BL	THR (OCR?)	Yes
04-01	Typed Page, Unsigned, Color Logo	Yes	No	ML	Cont Tone	Yes
04-02	Typed Page, Unsigned, Color Logo	Yes	Yes	BL	THR (OCR?)	Yes
06-01	Handwritten (ink)	Yes	No	BL	Cont Tone	Yes
11-01	B/W Photo, Circuit Board	No*	No*	ML	Cont Tone	Yes
13-01	Image Standards, Fax Chart	No*	No*	ML	Cont Tone	Yes
14-01	Form, Blank (Green)	No	No	BL	Cont Tone	Yes
15-01	Form, Completed (Red Stamp)	No	No	BL*	Cont Tone	Yes
16-01	Eng Drawings, Versatec Plot	No	No	BL*	Cont Tone	Yes
17-01	Circulars (Newswk Ad) Multicolor	Yes	No	ML*	Cont Tone	Yes
0(148)	Fairchild Letter	Yes	Yes	BL	THR (OCR?)	Yes
0(148)	Fairchild Letter, Corrected	Yes	Yes	BL	THR (OCR?)	Yes
0(456)	Fairchild Letter	Yes	Yes	BL	THR (OCR?)	Yes
0(456)	Fairchild Letter, Corrected	Yes	Yes	BL	THR (OCR?)	Yes
0(820)	Fairchild Letter	Yes	Yes	BL*	THR (OCR?)	Yes
0(820)	Fairchild Letter, Corrected	Yes	Yes	BL	THR (OCR?)	Yes
0(1208)	Fairchild Letter	Yes	No	BL	Cont Tone	No
0(1208)	Fairchild Letter, Corrected	Yes	No	BL*	Cont Tone	No

histogram. Asterisks are shown on the three columns of the chart where marginal decisions could be misinterpreted by an algorithm. An image such as a black and white photograph – having horizontal and vertical SFI parameters much like those of typing and being generally bilevel in nature – might be misinterpreted as a typed page, by having either the proper spatial frequency content or/and PBS histogram. It is recognized that for almost any criterion we establish it will be possible to postulate an image which would defeat proper classification. The column second to the right in table B1 indicates the decisions as a result of having used only these three parameters for classification. The rule invoked was the following: if SFI_v and SFI_h are present and PBS indicates bilevel, the decision is made to threshold the data and submit as a candidate for OCR. The absence of any one of the three parameters causes a vote to exploit the full 6 bits of resolution and treat the image as if it were a continuous-tone image. The last column on the right of table B1 shows the correctness of the decision using only these three parameters. It indicates that in all cases except in the Fairchild letter image 0(1208), both corrected and uncorrected, the decision was a proper one. Image 0(1208) was a bilevel image and as such should have been classified for thresholding and candidacy for OCR scanning. However, because of the poor print contrast ratio (0.152), the SFI_h amplitude was practically negligible and it was judged that an automatic detector for this feature might not reach its threshold.

However, in examining image number 0(1208), it is extremely doubtful that a successful threshold operation could have been achieved on this image in the first place, and perhaps it was a correct decision on the part of the three-parameter algorithm to submit this to full continuous-tone processing at the offset.

The results of the tests so far indicate that there is a great deal of promise in classification of images which need only to be thresholded and which may be candidates for further compression through OCR. Further studies on this subject will be undertaken during the coming year.

SELECTIVE FILTERING

A short discussion was given on page A-7 (appendix A) of this report regarding the odd/even response of the Fairchild imaging device. The result of that investigation showed in figure A6 that the odd pel output is consistently less than the even pel output given the same stimulus. Figures A7, A8, A9, A10, and A11 all of appendix A show the results of illumination correction on the odd/even responses shown in figure A6. It can be seen in these figures that there are a number of excursions of one or two levels in amplitude followed by a return to the original level. Such changes in amplitude of one pel brightness level cause a shortening or truncation of run lengths which decreases the compressibility of the image.

One of the potential methods of minimizing the effects of these 1-level brightness amplitude excursions is the use of a selective filter. The selective filter can be programmed to accommodate excursions in pel brightness between successive pels of integer values (one, two, three, etc) and may be programmed to accommodate pel brightness change durations of one or more spatial increments.

The top curve, figure B27 (a), shows greatly magnified portions of a typical brightness profile. In the left side of figure B27 (a) the data are seen to exist at level 43. For one pel time (spatial sample), they rise to 44 and again return to level 43, where they exist for at least two clock periods. Then it rises to level 44, 45, and so forth. The numbers which appear beneath the curve across the page indicate the number of times that the run length of the least significant bit plane would be aborted and a new run length code would be required to define the data shown in the figure.

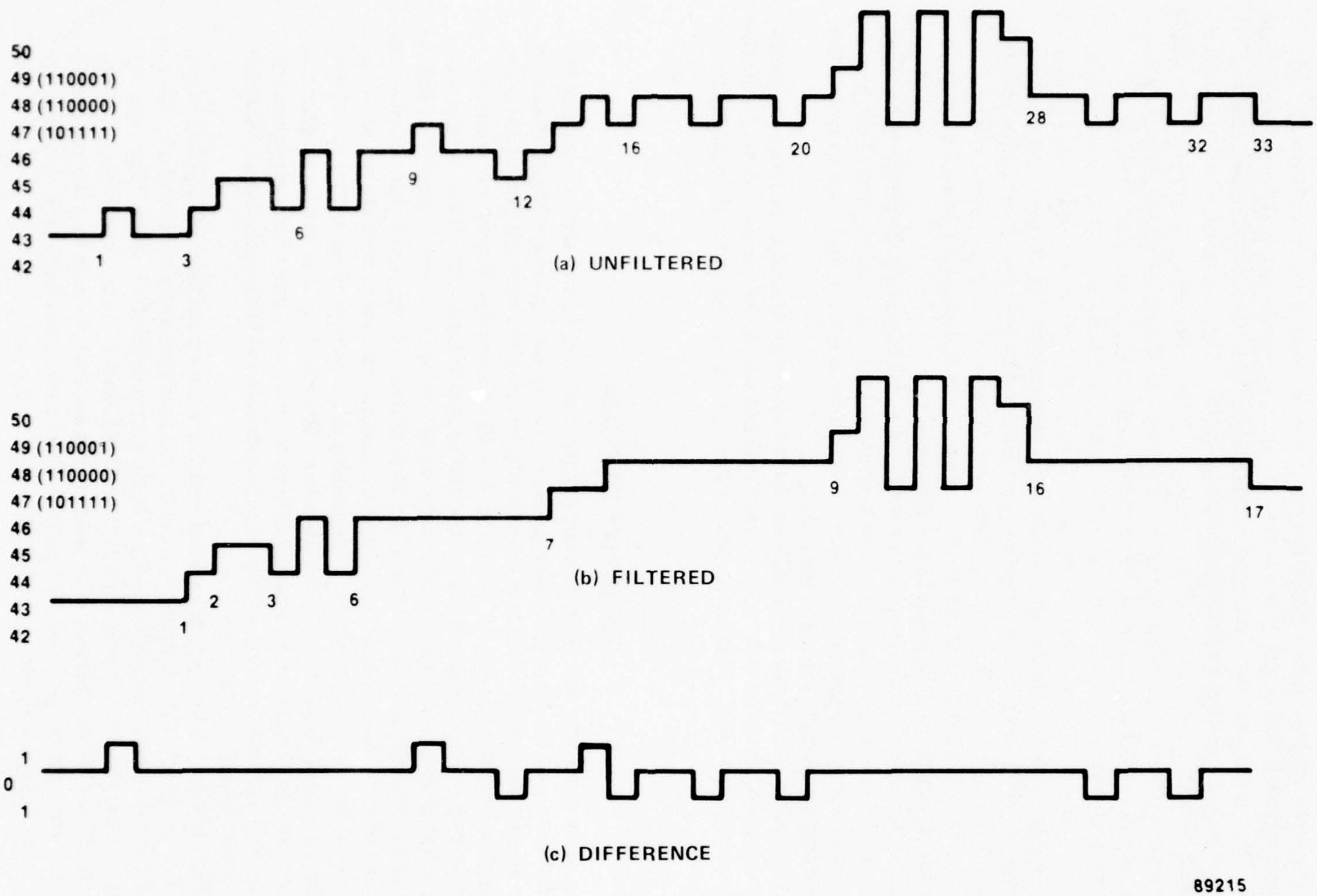


Figure B27. Selective filtering.

With selective filtering it is possible to apply a simple rule such as the following: if the pel brightness amplitude increases by one brightness level, exists at the higher brightness level for a duration of one pel period, and then returns to the original brightness level – or, conversely, if it exists at a brightness level, falls by one brightness level, exists at the lower brightness level for one pel period, and then returns to the original level – then this excursion shall be considered as an invalid or noise amplitude excursion and shall be filtered out. An example of such an excursion is shown immediately at the left of figure B27 (a). The data begin at level 43, increment to level 44, last for one pel period, and return to level 43. By invoking our filter rule on such data, it is possible to remove this excursion from the digital data as shown in figure B27 (b) immediately below. Here the data remain at level 43 throughout the short increment of time which would otherwise have had the small excursion and return.

Invoking this rule on this entire line shown in curve (a), it is possible to remove almost 50% of the changes in brightness levels. This will greatly increase the compressibility of the image. The pel amplitude differences which were removed from the image upon transmission are shown in figure B27 (c). This difference curve shows that eight pairs of excursions were removed from the simple curve shown above.

Figure B28 shows one configuration of the spatial filter characteristics. The small square shown at the upper left of the curve is the only feature area of information removed from the entire passband of the system by the filter. This is labeled in the figure as the filter stop band. This area within the filter stop band can be made programmable to encompass more than one difference level and more than one spatial frequency. The single square shown in the figure is set at the Nyquist limit (maximum spatial frequency), encompasses only one brightness difference level, and is equivalent to the example previously described. All other conditions of brightness excursion and spatial frequencies are allowed to pass by the particular configuration of the spatial filter shown. In other words, if the resolution of a picket fence being scanned was exactly at the maximum spatial scan frequency of the system but the brightness difference between the pickets and the background was two brightness levels, the image would be transmitted. Or, if the spatial frequency of the picket fence was such that two pels encompassed each picket and two pickets encompassed the interspace between pickets but the brightness level difference was as low as one level, this image would also be passed on as true information rather than noise.

On the left side of figures B27 (a) and (b) are shown some typical values of pel brightness which might be encountered in scanning a typical typed page. These include brightness levels between 42 and 50. The binary numbers for 47, 48, and 49 are shown immediately to the right of these brightness numbers. These binary numbers are presented most significant bit first. It can be seen that an excursion from level 47 to 48 causes 5 of the 6 bits in the binary number to change. Any excursion back and forth between the brightness levels of 47 and 48 causes run lengths in five of the six bit planes to be interrupted, greatly reducing the compressibility of image data. Figure B27 (b) shows the appreciable smoothing capability of the filter and the actual count of the number of brightness level changes, which has been reduced from a total of 33 to a total of 17. The difference curve shown by subtracting the filtered profile from the unfiltered profile is shown in figure B27 (c). These 1-level differences do subtly modify the actual image but are generally imperceptible to the viewer.

Figure B29 represents the results of the application of the programmable filter on a portion of a typed page. This page has been illumination corrected. Figure B29 has been divided into three columns. The left column shows the binary data in each of the six bit planes for the same portion of the image. Bit plane 1 is defined as the least significant bit.

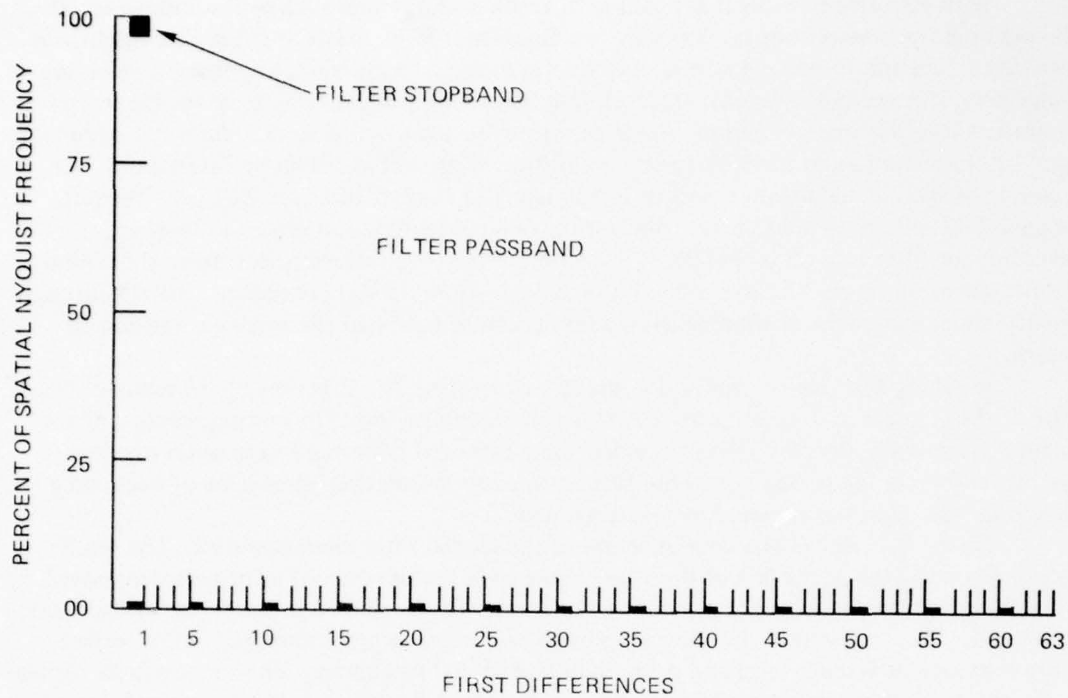


Figure B28. Spatial filter characteristics.

The texture of the less significant bit planes in figure B29 shows a tendency toward vertical stripes as a result of nonuniformity of the imager response. Some of this may be attributed to optical variation in the geometry or sensitivity of the device, but the remainder can be attributed to the odd/even response problem discussed in appendix A. By comparison, the center column shows noticeable improvement from using the programmable spatial filter.

The dots shown in the right column indicate the locations of otherwise truncated run lengths which now are contiguous runs after filtering.

Figure B30 shows the results of using the same type of filter in the recursive mode, which accommodates odd/even/odd/ — — sequences somewhat differently. The recursive mode uses the modified rather than the original data string as captured, to look ahead and operate on pel sequences. The recursive version reduces odd/even/odd/ — — sequences to single brightness value runs at either the upper or lower of the two brightness levels. Since the present imager driver electronics cannot compensate for the odd/even imager differences, the recursive mode should provide the better compressibility improvement for presently acquired images.

Table B2 (a) gives the statistics obtained by using a 3-bit variable-length code algorithm for the compressibility of the unfiltered image which has previously been illumination corrected. Table B2 (b) shows the compressibility of the same image after nonrecursive filtering and indicates an improvement in the compressibility of the image of approximately 38%. Table B2 (c) shows the effect of the recursive mode as opposed to the nonrecursive version. The recursive version affords a 53% improvement in the compressibility of the image using the 3-bit variable-length code. All values shown in table B2 are for full-page images, not just the small areas shown in figures B29 and B30.

More investigation on this subject is planned to improve the compressibility of images and the cosmetic appearance of the image when printed or displayed.

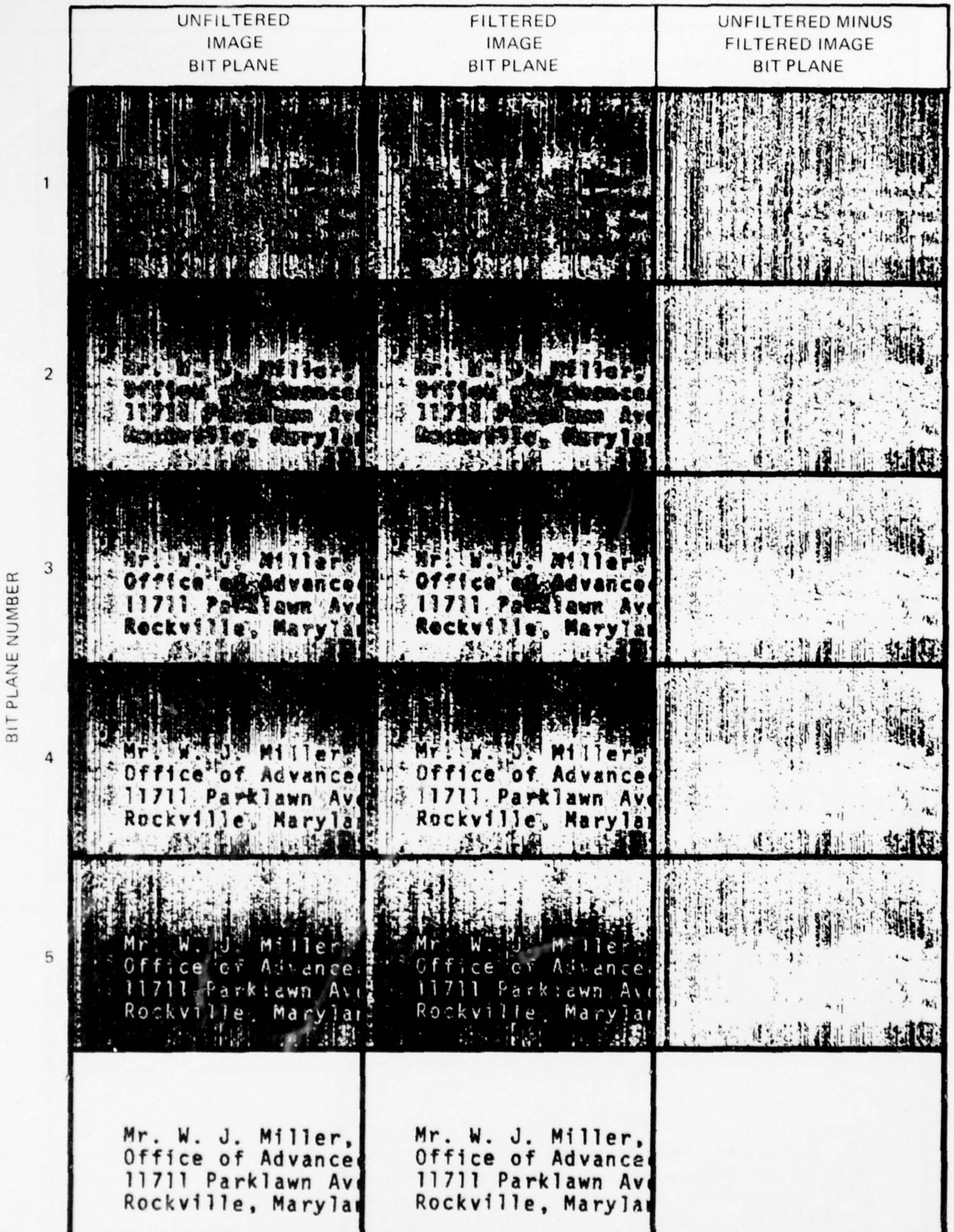


Figure B29. Results of programmable filtering (nonrecursive).

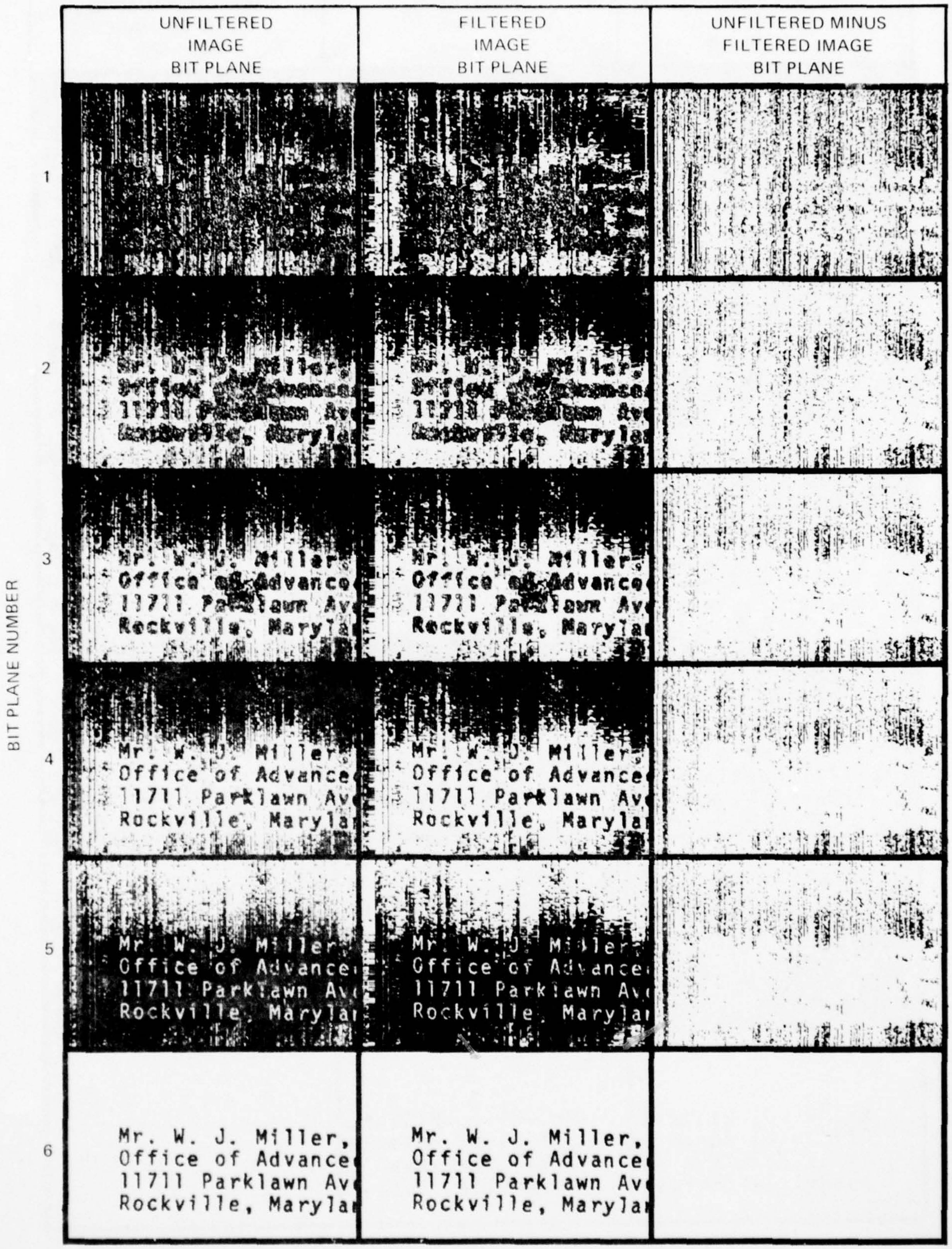


Figure B30. Results of programmable filtering (recursive).

Table B2. Compression ratio analysis.

Word Length	Bits To Be Transmitted: Bit Plane 1	Bit Plane 2	Bit Plane 3	Bit Plane 4	Bit Plane 5	Bit Plane 6
3	3776481	2106162	1233489	937707	804576	108687
4	655396	478808	292148	251472	234224	68344
6	251346	345504	230388	236196	242574	124716
8	41696	191392	152256	133952	132864	47872
10	1890	85620	75010	72270	71740	27180
12	0	23724	40116	34212	33204	11412
14	0	4466	39970	30436	30044	15358
16	0	224	16960	29840	29952	23792
18	0	0	4428	7596	8676	10062
20	0	0	320	1320	1840	22220
22	0	0	0	0	0	0
24	0	0	0	0	0	0
26	0	0	0	0	0	0
Total	4726809	3235900	2085085	1735001	1589694	459643
C.R.	0.791	1.156	1.794	2.156	2.353	8.137

Total Bits = 13832132 Overall C.R. = 1.622

(a) Without selective filtering

Word Length	Bit Plane 1	Bit Plane 2	Bit Plane 3	Bit Plane 4	Bit Plane 5	Bit Plane 6
3	1740939	1208241	815322	569667	439887	108540
4	603980	373700	231064	195900	178984	68320
6	494034	340722	214542	227694	234294	124716
8	198904	223752	152144	140376	139080	47856
10	28420	123110	93380	83780	83250	27180
12	1812	49128	44544	39960	38964	11412
14	0	11662	40712	30576	29974	15344
16	0	1888	21168	32560	32704	23776
18	0	0	5922	8784	9810	10080
20	0	0	860	1840	2380	22220
22	0	0	0	0	0	0
24	0	0	0	0	0	0
26	0	0	0	0	0	0
Total	3068089	2332203	1619658	1331137	1189327	459444
C.R.	1.219	1.604	2.309	2.810	3.145	8.140

Total Bits = 9999858 Overall C.R. = 2.244

(b) With nonrecursive filtering

Table B2. Continued.

Word Length	Bit Plane 1	Bit Plane 2	Bit Plane 3	Bit Plane 4	Bit Plane 5	Bit Plane 6
3	1305486	1000650	708396	474396	344931	108540
4	530396	335728	213080	178512	161624	68320
6	499542	324702	202824	218238	224760	124716
8	269368	237208	154528	144200	142944	47856
10	55090	139500	102340	89830	89270	27180
12	4104	57792	48744	44316	43380	11412
14	0	12964	41720	31276	30618	15344
16	0	2048	21648	32960	33104	23776
18	0	0	5922	8820	9846	10080
20	0	0	960	1900	2440	22220
22	0	0	0	0	0	0
24	0	0	0	0	0	0
26	0	0	0	0	0	0
Total	2663986	2110592	1500162	1224448	1082917	459444
C.R.	1.404	1.772	2.493	3.054	3.454	8.140

Total Bits = 9041549 Overall C.R. = 2.482

(c) With recursive filtering

Compression Ratios — 3-Bit Variable Length Code

WJM Typed Page — Pre-Scan — Illumination Corrected

Image on 067/08 Stats on 068/09

FUTURE NOSC PLANS

This data base study has produced some encouraging results particularly leading to the potential ability to classify typed pages which may be thresholded into bilevel images at a savings of six-to-one in image storage requirement and/or transmission bandwidth. It also provides a prototype strategy to identify candidate documents for OCR equipment and for further bandwidth compression of typewritten type mail. Planned future NOSC activities are listed below in approximate order of importance.

1. Continue acquiring images in the data base and examining candidate characteristics which will help classify images into major categories.

2. Improve the uniformity of response of the illumination, optics, and sensor characteristics to facilitate the automation of the PBS histogram and the SFI process. It is felt that this will also reduce the odd/even response problem at and near the edges of images where errors are now magnified by the illumination correction process.

3. Develop and test a number of automatic category selection algorithms with emphasis on those which, with high probability, can detect typewritten type mail.

APPENDIX C:

PAPER REFLECTANCE AS A FUNCTION OF DATA DENSITY AS SEEN BY A HIGH-RESOLUTION REFLECTOMETER

by

WR Robinson
Code 8235
Naval Ocean Systems Center

THE PROBLEM

It has been observed in the scanning of many different materials and styles of printing over the course of the USPS/NOSC program and the subsequent review of the recorded data that the reflectance of paper appears to be less in the vicinity of high-density printing than it is for the base unprinted paper. In order to better substantiate this phenomenon, some experiments were devised and performed to demonstrate the degree of the problem and evaluate the necessity for further, more detailed, experimentation.

After the initial experiments were started, the question of the measuring system spatial and temporal response arose. In order to ascertain these parameters, three different test targets with varying degrees of edge sharpness were scanned. In order that no doubts would arise later as to system response, different light sources and objective lenses were also used in the scanning for the evaluation of the test equipment.

OBJECTIVES

The objectives of this study were:

1. To look at the reflectance characteristics of various substrates (papers) as a function of spatial density of high-contrast data.

2. To verify that the spatial or temporal response of the measuring system was not degrading the data of objective 1.

APPROACH

The approach used to meet objective 1 was to scan with a high-resolution scanning reflectometer various areas of a page typed full with the Postal bar code. See figure C1. In order to have a broader base from which to evaluate the problem, two types of paper were used: (1) a high-rag-content white "bond" paper and (2) a smooth white paper. Both papers were approximately 0.004 inch thick. Various areas of each test sample with varying data densities were scanned with the reflectometer and scan recordings were made. Tests 1-3 address this objective.

The second objective was accomplished by scanning small areas on two types of resolution-measuring targets: the IEEE facsimile test chart and an Air Force resolution test slide. These targets were scanned with the same setup used for objective 1 and with different light sources and objective lenses for the reflectometer. Tests 4-6 address this objective.

Figure C1. Test sample 1 facsimile – actual sample was made with white bond paper. Test sample 2 was made on smooth white paper.

EQUIPMENT USED

A Gamma Scientific 700-10-09 scanning microdensitometer set up as a microreflectometer was used to scan the various test documents. The readout for the reflectometer was a Hewlett-Packard 7034A X-Y recorder. The scanning aperture was a Gamma Scientific 700-10-33 eyepiece which has a 3-by-100-mil active area. The effective area of scan is

determined by the power (magnification) of the objective lens. Five- and 10-power objectives were used. The effective magnifications were 3.6 and 8.7, which produced actual scanning windows of 0.8 by 28 mils (22.4 $mils^2$) and 0.34 by 12 mils (4.1 $mils^2$), respectively. The narrow dimension was aligned with the direction of scan. The 5-power objective was used exclusively in performing tests for objective 1, whereas both objectives were used in performing tests for objective 2. Also, the reflectometer's light source was used exclusively for the objective 1 testing whereas two light sources were used for objective 2 testing. They included the reflectometer light source and a half-milliwatt helium-neon laser.

TEST DESCRIPTIONS AND DISCUSSION

TEST 1

Test sample 1 (fig C1), a white bond paper, was scanned in several areas. The results are shown in figures C2–C6. The actual bar code scanned for each scan is reproduced on the respective test charts. The long rectangular boxes superimposed on the bar code show the actual area scanned. In order to prove that the very erratic traces were due to the test sample and not the reflectometer's photomultiplier, several scans were made in both directions. Scans 1–6 (fig C2–C4) were scanned at a chart resolution of 10 mils (0.010 inch) of test sample per centimetre of chart travel, which shows the bond paper noise very clearly. However, this resolution did not cover very many bars, so all subsequent scans for objective 1 were done at 40 mils/cm. Scan 11 was a repeat of scan 10 (fig C6). It was repeated so that scans 9 and 10 could be separated more easily.

The most striking point about the data gathered in this test was the apparent noise content in the recorded signals. In several instances the peak-to-peak noise was at least 40% of the average signal excursion. It was stated above that the test samples were scanned in both directions to determine whether the noise was due to the bond paper or photomultiplier noise (fig C2–C4). It can be said unequivocally that the noise is due to the bond paper as each retrace agrees exactly with the original in shape. The displacement errors are due to variations in scanner motion.

The answer to the important question of how much, if any, does paper reflectance change as a function of spatial density, ie, objective 1, is not so obvious or dramatic. From the data collected, however, it can be said with certainty that the phenomenon does exist. With the fixed density of the Postal bar code and the bond paper used for test sample 1, the drop in paper reflectance between adjacent bars ranges from a low of 10% to a high of at least 30%. Scans 6 and 7 (fig C4 and C5) show the drop most conspicuously, but it can be measured on all scans. It should be noted that, for this report, the scanning window had a high aspect ratio, ie, approximately 1 by 23 mils, whereas the operational requirement is 5 by 5 mils. It is the judgment of the writer that the reduction of reflectance could be more significant with the square window. A square-aperture eyepiece for the scanning reflectometer was not available.

TEST 2

For this test, the Postal bar code was typed onto a smooth white paper, test sample 2, and only two scans were made. The scans, 12 and 13, are reproduced in figure C7 along with the superimposed bar code.

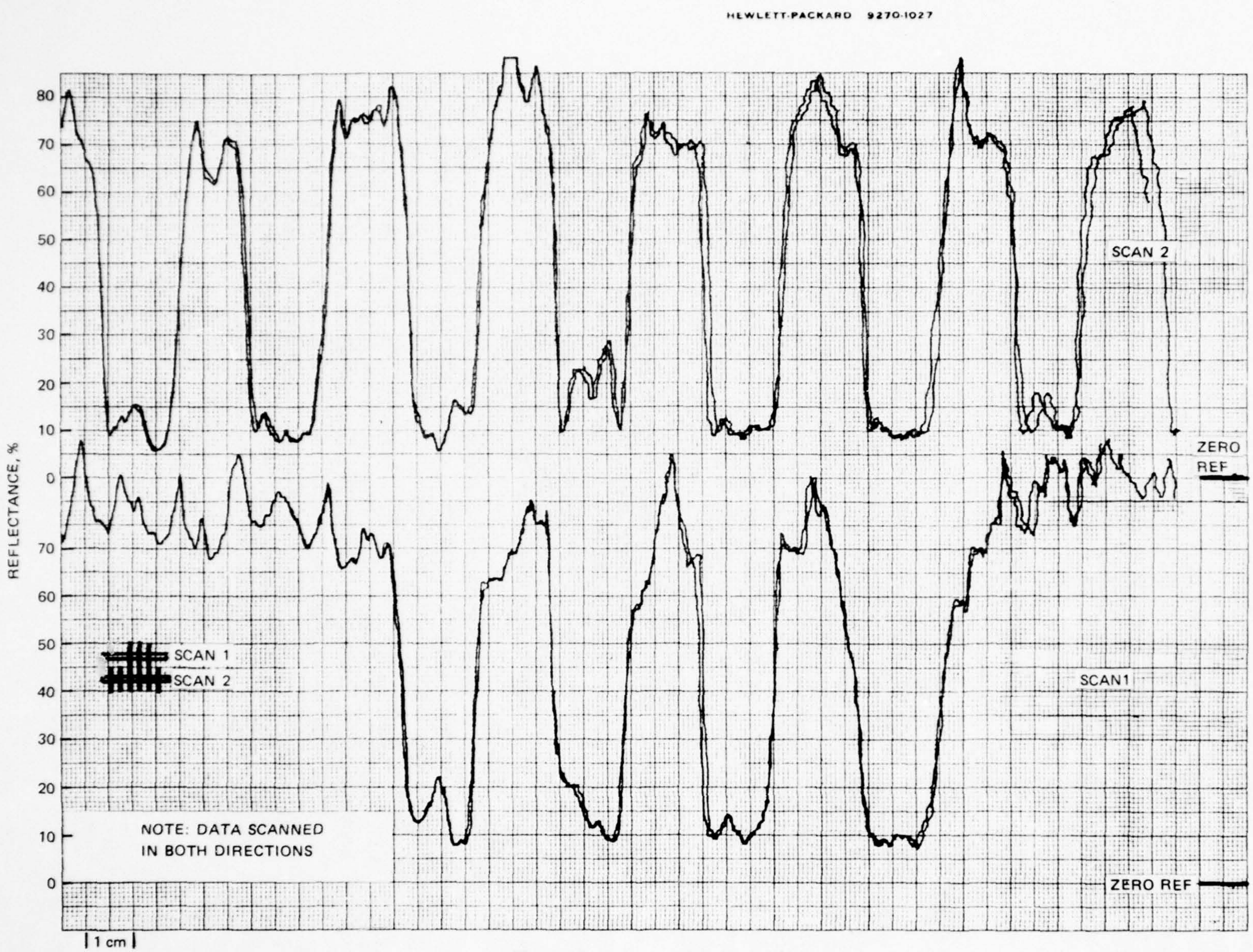


Figure C2. Scans 1 and 2, 10 mils/cm.

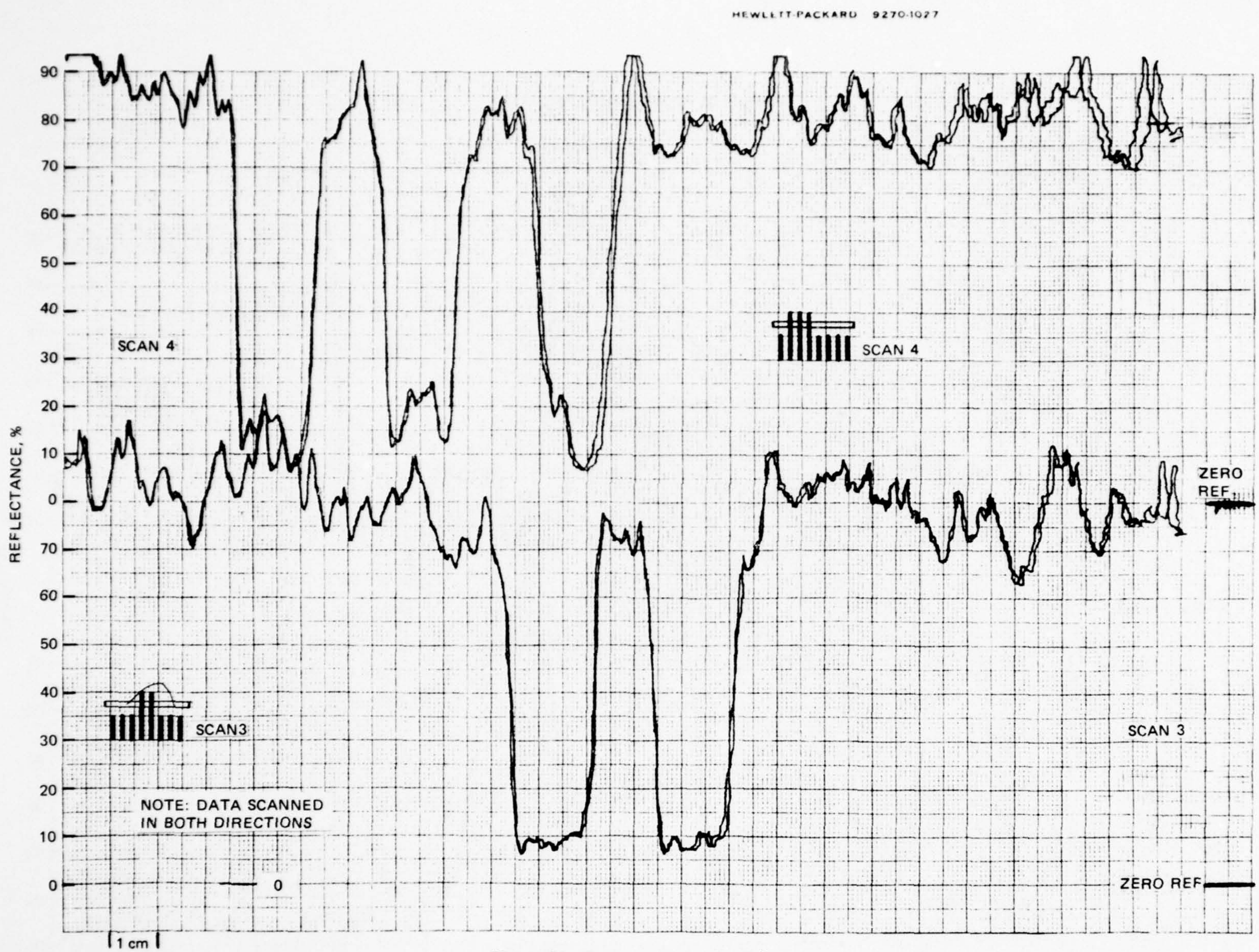


Figure C3. Scans 3 and 4, 10 mils/cm.

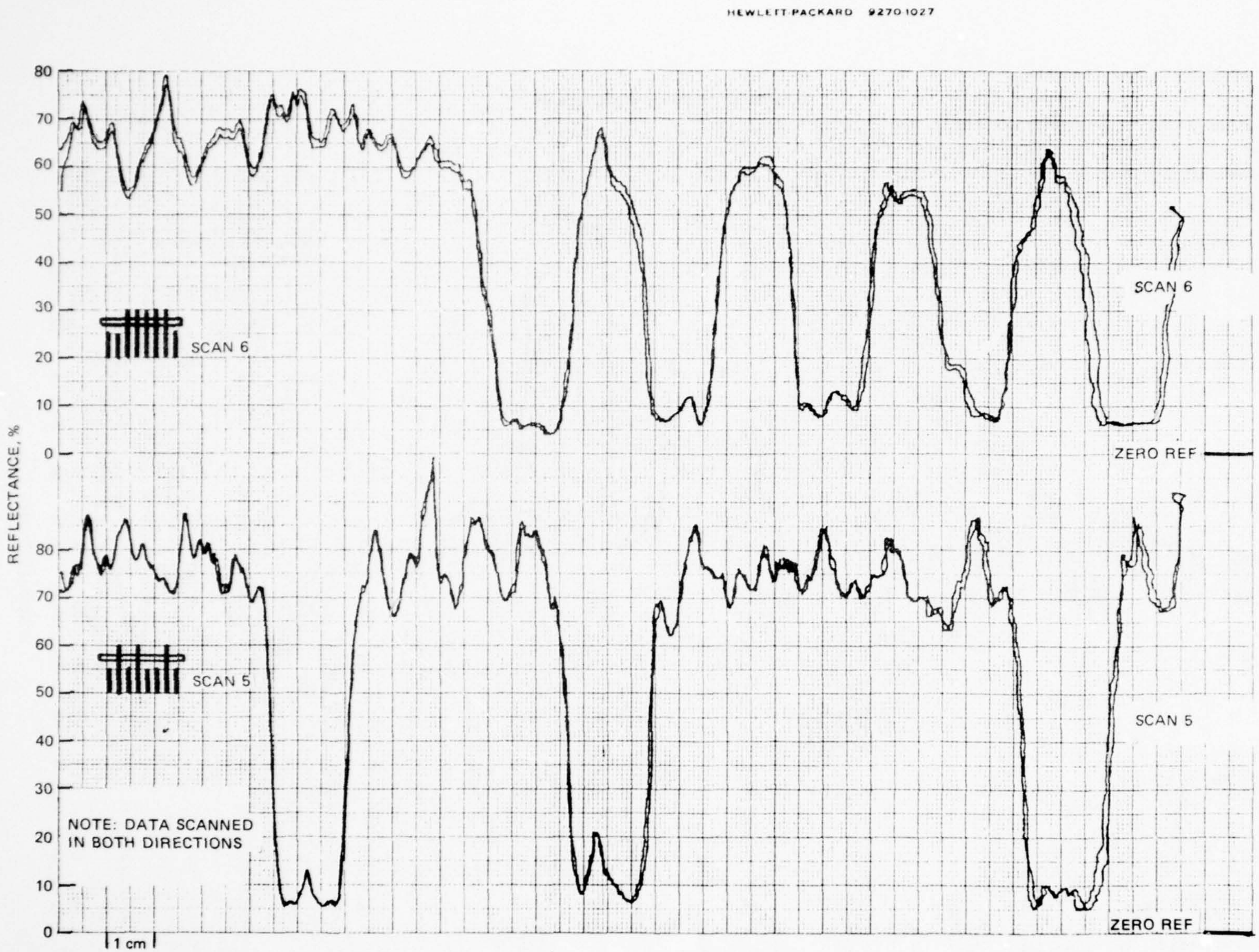


Figure C4. Scans 5 and 6, 10 mils/cm.

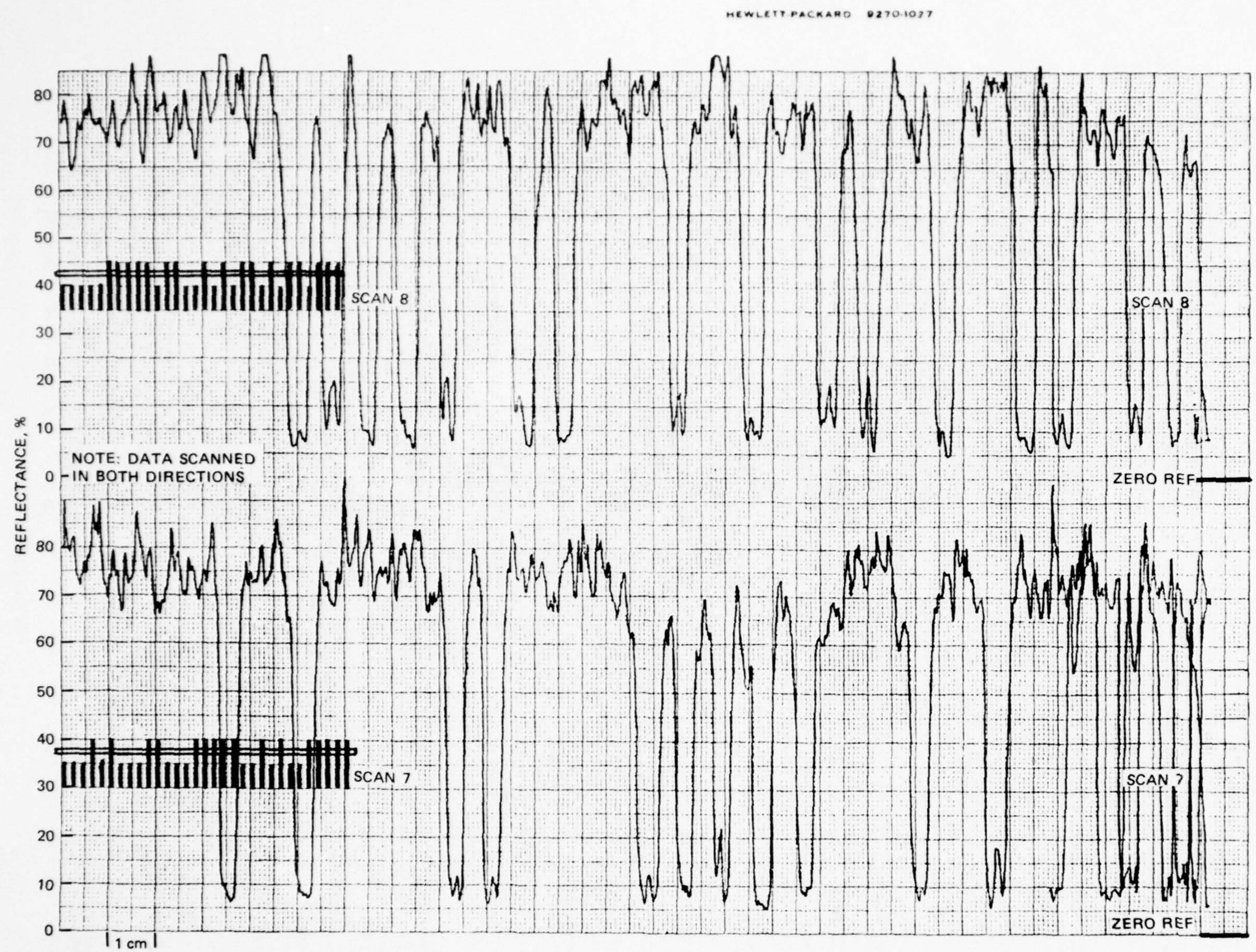


Figure C5. Scans 7 and 8, 40 mils/cm.

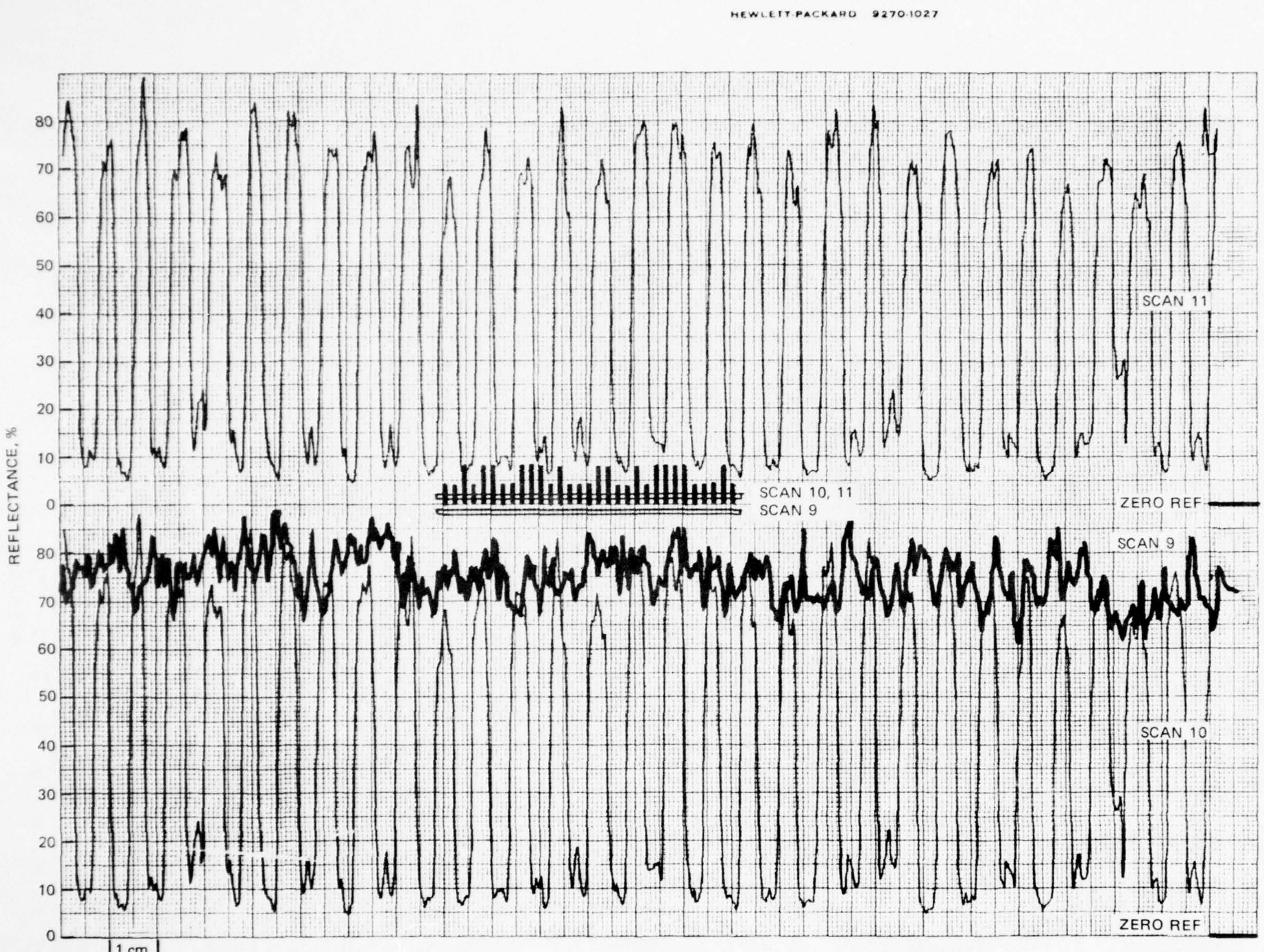


Figure C6. Scans 9-11, 40 mils/cm.

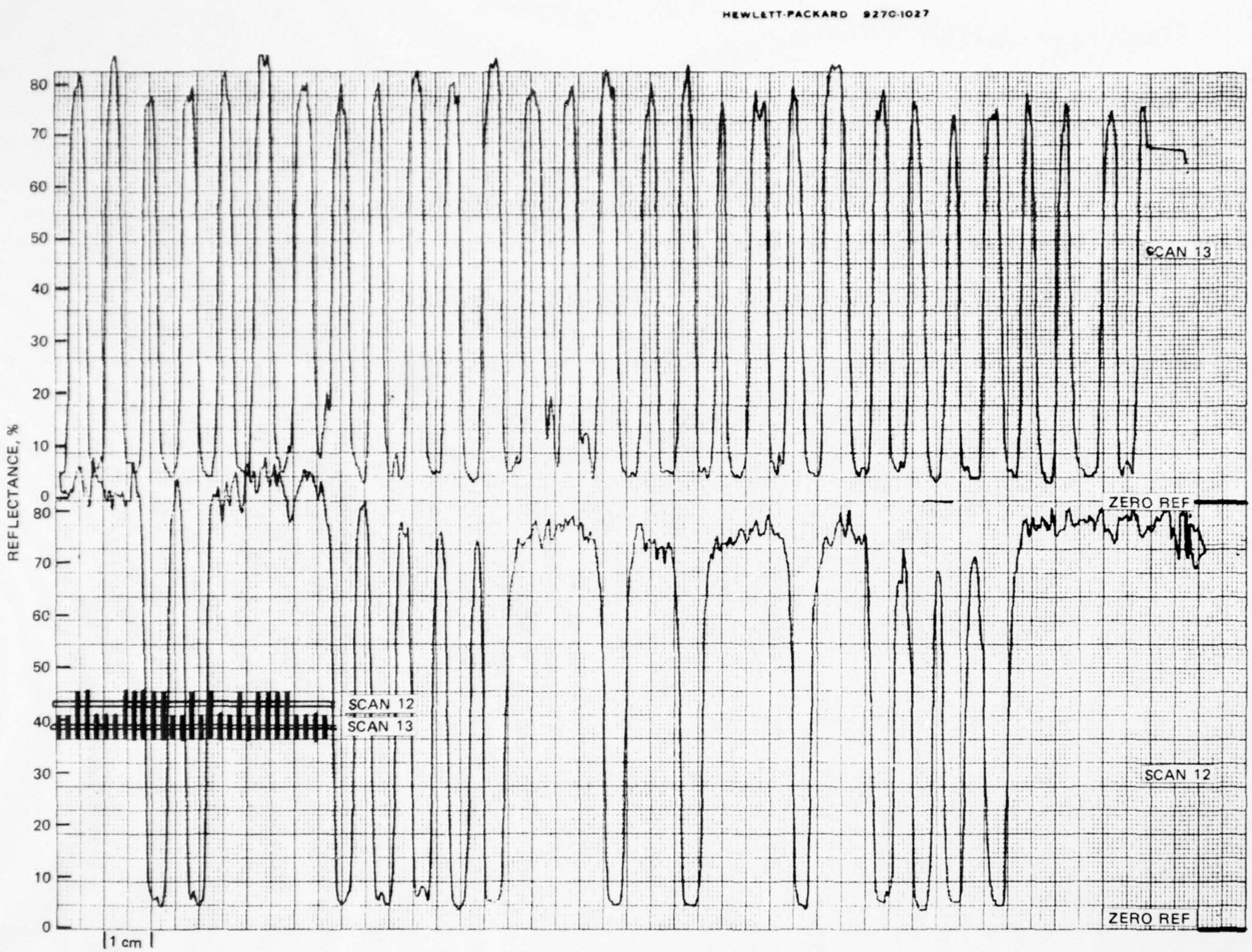


Figure C7. Scans 12 and 13, 40 mils/cm.

AD-A070 546   NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA   F/G 9/5
ADVANCED MAIL SYSTEMS SCANNER TECHNOLOGY. EXECUTIVE SUMMARY AND--ETC(U)
OCT 78 F C MARTIN, T R LITTLE, L A WISE

UNCLASSIFIED   NOSC/TR-358   NL

2 OF 2
AD
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8-79
DDC

A comparison of the scans in figure C7 with those in figures C5 and C6 shows that there was marked reduction in paper noise. The reduction in paper reflectance was, nevertheless, still present and was on the order of 12%, which compares with the 10–30% for the bond paper used in test 1.

TEST 3

This test consisted of scanning letters typed on the same kind of paper as test sample 2 and letters printed on a telephone call memo slip. A reproduction of the test samples is shown in figure C8. Scans 14 and 15 (fig C9) are the results of scanning the alphabetic characters.

Again it can be determined that the papers are relatively smooth from the low level of noise in the background reflectance. The reduction in reflectance due to spatial density is not so pronounced, however. In scan 14 it appeared to be about 7%, whereas in scan 15 it may have been as much as 20%.

TEST 4

In order to show that the instrumentation was not the cause of the reduced reflectance noted in the previous tests, this test and those following were conducted. For this test, patterns 3–5 and 9 of the IEEE facsimile test chart, STD 167A-1975 (fig C10 and C11), were scanned one or more times and the results are reproduced in figure C12. Test scans 17 and 22 are of the same IEEE chart pattern. The difference is that scan 22 was made with the noise filter removed from the recorder's vertical input. There appears to be no improvement in the squareness of the recording. Scan 23 is of the same areas as scan 22. The difference is that X gain of the recorder was increased by a factor of 4 to give 10-mil/cm resolution instead of the 40-mil/cm resolution used for scans 16–22. The most prominent point about these data is that the sharpness of the IEEE chart appears to the eye to be much better than the recordings in figure C12 show.

Scans 19–21 and 24 are all of pattern 9, the variable-resolution bars. Some improvement in pattern sharpness is noticeable in scan 21 over scan 20, which is the result of removing the filter.

TEST 5

The scans recorded in figure C11 all seem to indicate lack of sharpness of the IEEE test chart. In an effort to be certain the instrumentation was not at fault, an Air Force resolution test slide was scanned with projected light used in lieu of reflected light. The Air Force test slide is a metal film slide with very low diffuse reflection; therefore, projected light had to be used in lieu of reflected light. Figure C13 shows the results of this series of scans. Only scan 25 was made with the noise filter connected. The difference between scans 25 and 26 is apparent, but it is not sufficient to change the results of previous tests. All the data taken so far were taken with a 5-power objective from Gamma Scientific. Another 5-power objective lens (about twice as expensive) was used for scan 28, which was the same area as scan 27. This objective appears to give a sharper pattern than the Gamma Scientific lens. The same area was scanned again with a 10-power lens. The results are shown by scan 29.

MEMORANDUM OF CALL

TO:

☐ YOU WERE CALLED BY— ☐ YOU WERE VISITED BY—

OF (Organization)

☐ PLEASE CALL → PHONE NO. CODE/EXT.

☐ WILL CALL AGAIN /2 ☐ IS WAITING TO SEE YOU

☐ RE ☐ WISHES AN APPOINTMENT

MESSAGE

28 mil path
thru middle of
letters

3-2-77
WRR

TEST SAMPLE 4

RECEIVED BY	DATE	TIME

STANDARD FORM 63
REVISED AUGUST 1967
GSA FPMR (41 CFR) 101-11.6

TEST SAMPLE 3

3-2-77
WRR

NAVAL OCEAN SYSTEMS CENTER
San Diego, California 92152

NOSCINST 5420.1
03/GWC:mtc
1 March 1977

NOSC INSTRUCTION 5420.1

To: Departments, Divisions, and Branches

Subj: Center Management Panel; estab

Lt side of marking

28 mil thru middle of lower case letters

1. Purpose. To establish the Center Management Panel (CMP) for planning

Figure C8. Test sample 3.

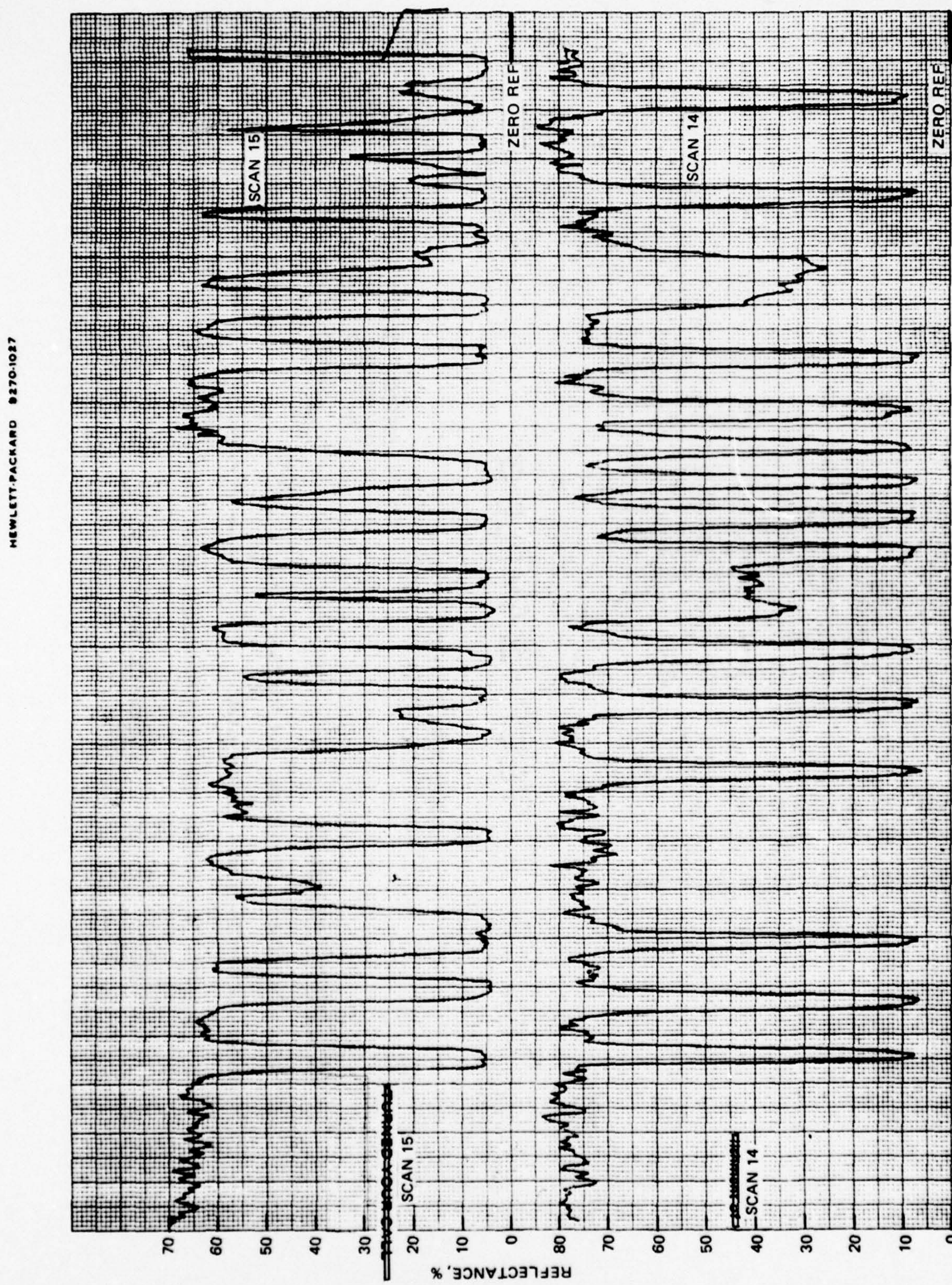

Figure C9. Scans 14 and 15, 40 mils/cm.

Figure C10. IEEE facsimile test chart.

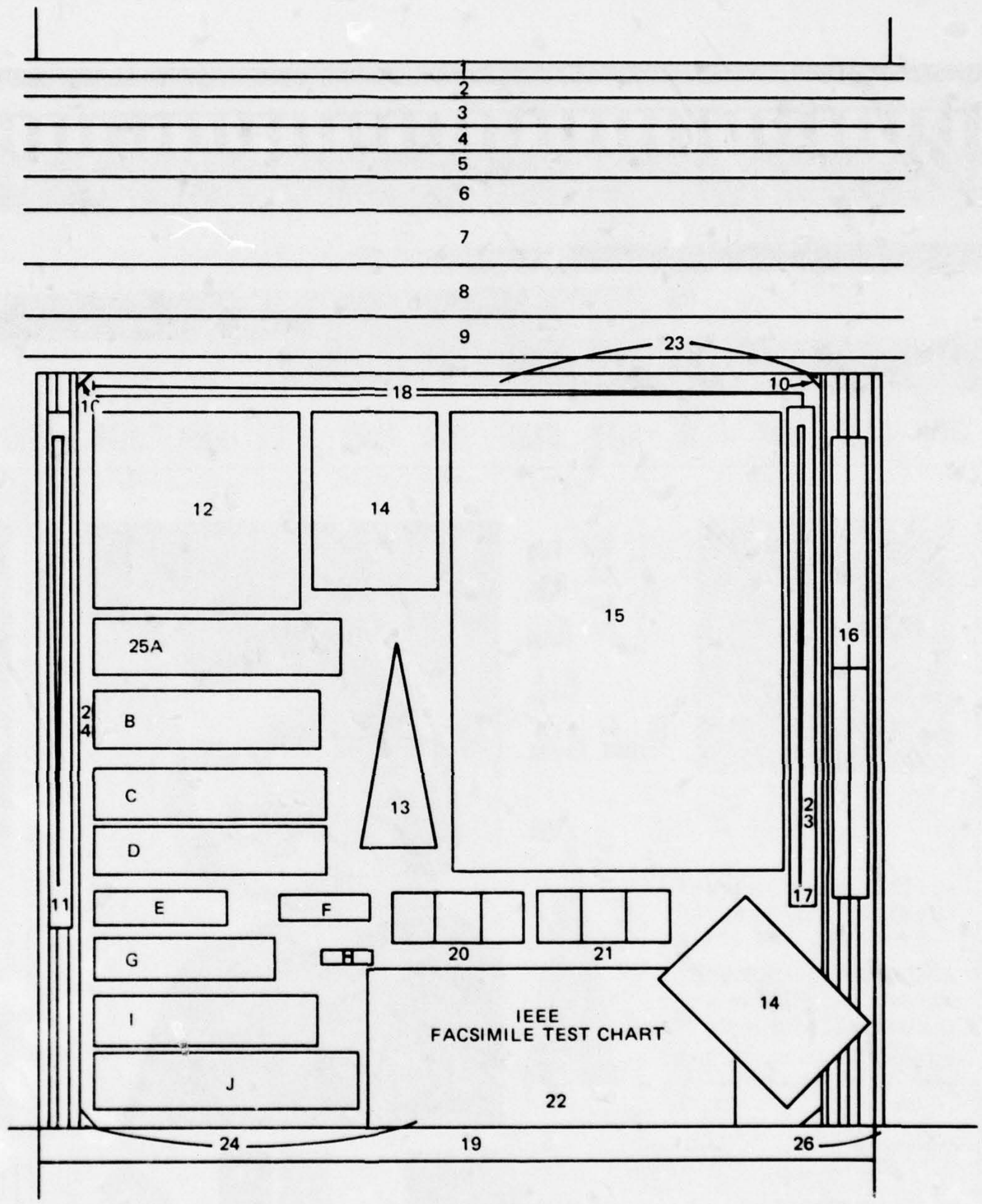

Figure C11. IEEE facsimile test chart pattern identification.

The conclusion to be drawn from this test is that the instrumentation rise time is not the limiting factor for the tests conducted prior to test 5 even with the recorder input filter in place. This is shown in a comparison of scan 25 of figure C13 with scan 23 of figure C12. The rise-time performance in figure C13 with the filter is about three times better than in figure C12 without the filter. A comparison of scan 26 in figure C13, which is without the filter, with scan 26 in figure C12 shows a response that is 5 or 6 times better.

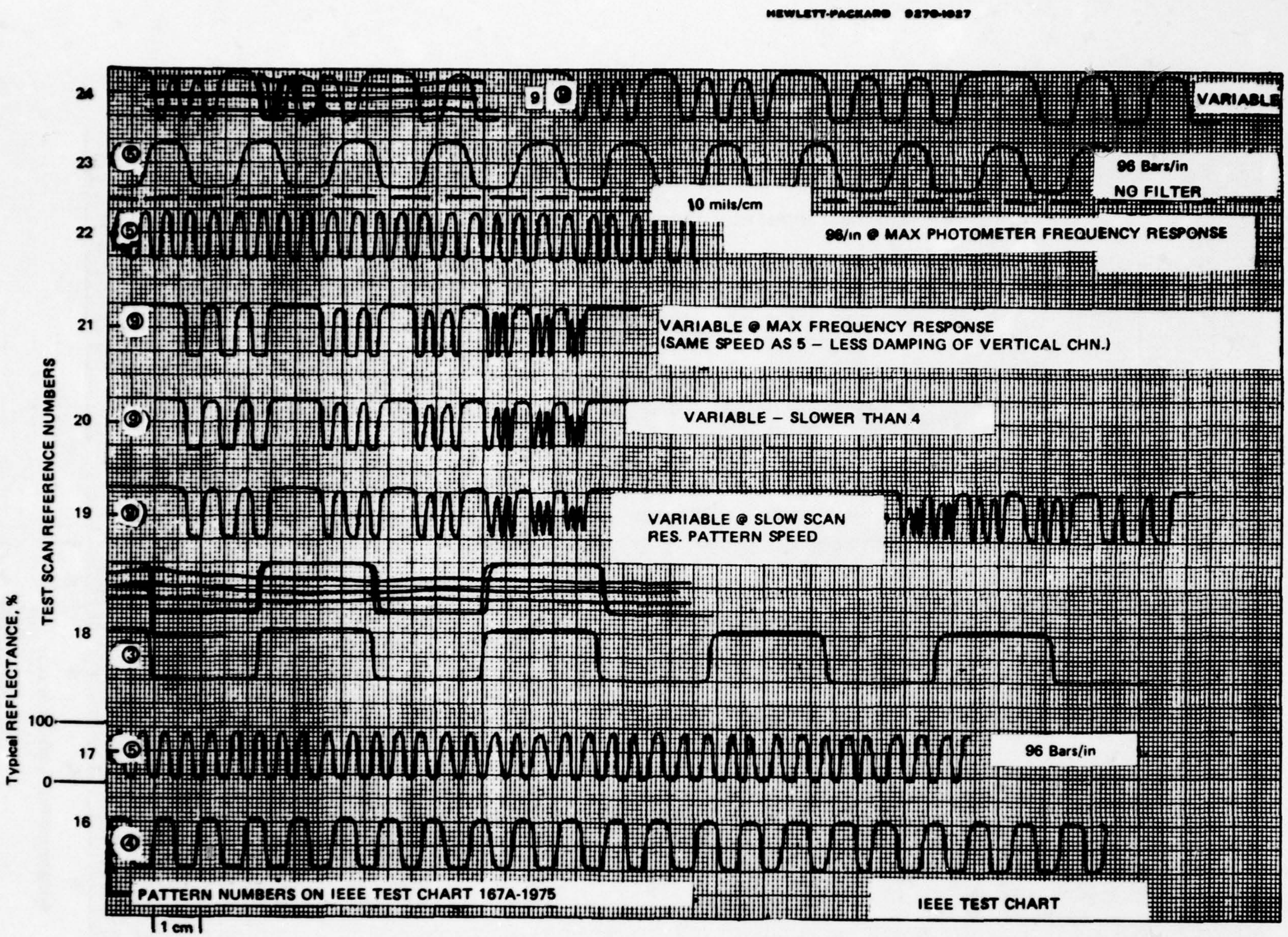

Figure C12. Scans 16-24, 40 mils/cm.

Figure C13. Scans 25–29, 10 mils/cm.

TEST 6

In a continuing effort to remove doubt as to whether the instrumentation was the cause of the apparent poor sharpness of the scans made of the IEEE test chart, pattern 5 (96 bars/inch) was scanned again with the 10-power objective lens used for scan 29 of figure C13. The results of this test, shown on scans 30 and 31 (fig C14), are with incandescent illumination, whereas scan 32 was made with helium-neon laser illumination. These changes in instrumentation produced no significant improvement in the sharpness of the scan over what was produced in scan 23 of figure C12.

From the results of this test and tests 4 and 5, it can be conclusively stated that the instrumentation was not causing the drop in reflectance of the paper as the spatial density of the imprinting increased. The filter used could have caused a problem had the test samples been scanned at a faster rate, but at the rate used it was not a significant factor.

CONCLUSION

From the data collected on this task it can be concluded that:

1. Bond paper is considerably more noisy, on the basis of high-resolution reflectance, than the other paper samples.

2. The printing on bond paper may also be more noisy.

3. High-spatial-density printing causes the reflectance of the paper to be lower than reflectance measured from the blank page.

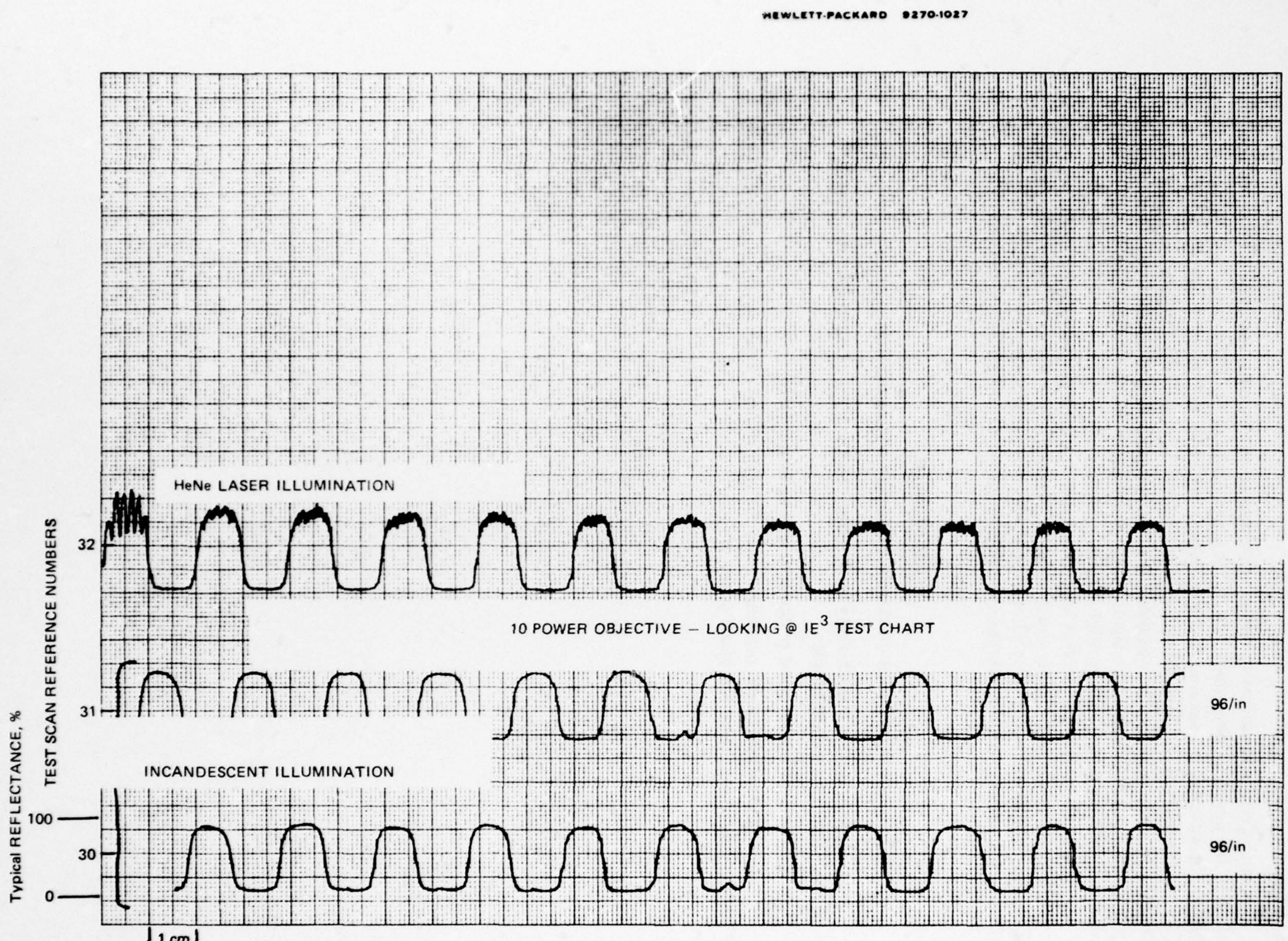

Figure C14. Scans 30–32, 10 mils/cm.

APPENDIX D:

IMAGE CAPTURE AND ANALYSIS SYSTEM

System Operator's Manual

by

JJ Lee Jr
San Diego State University Foundation
San Diego, California

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INTRODUCTION

This manual was prepared as a system operator's manual for the USPS/NOSC Image Capture and Analysis System (ICAS) (fig D1, D2).

The manual includes procedures for preparation for ICAS and scanner operation; loading of software; and capture, display, and printing of test images, correction tables, and statistics. Also included are sections describing the large drum test bed (LDTB) function control, 4051 terminal system commands, and common error recovery.

POWER UP

The memory interface unit (MIU) and memory control unit (MCU) contain lever switches on their front panels which must be set at appropriate positions before the ICAS is powered up.

MIU SWITCHES

1. Top left switch bank – 30 000
2. Center switch banks – 00
3. Top right switch – 2
4. Bottom right switch – 2

MCU SWITCHES

1. Position lever switch set – 0 (16 zeros)

The outside power source and the following equipment must be turned on before the ICAS system in NOSC building 33 will operate correctly:*

1. Three lower 110-volt circuit breakers located on the east wall of room 3306.
2. MCU power supply
3. MIU power supply
4. Tektronix 4051 terminal
5. Kennedy magnetic tape system

BOOTSTRAP

In order to load programs in the ICAS, two load operations must be performed, one on the Tektronix 4051 terminal and the other on the MCU.

1. Locate the cartridge tape labeled "Terminal Executive." Insert this tape into the 4051 tape drive. Wait for all indicators, except power, to go off and press AUTO LOAD. Answer any questions prompted on the 4051 screen followed by RETURN. (At the present time two memory modules are in operation.)

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*One or more memory modules are assumed to be connected and powered up when the main power is turned on.

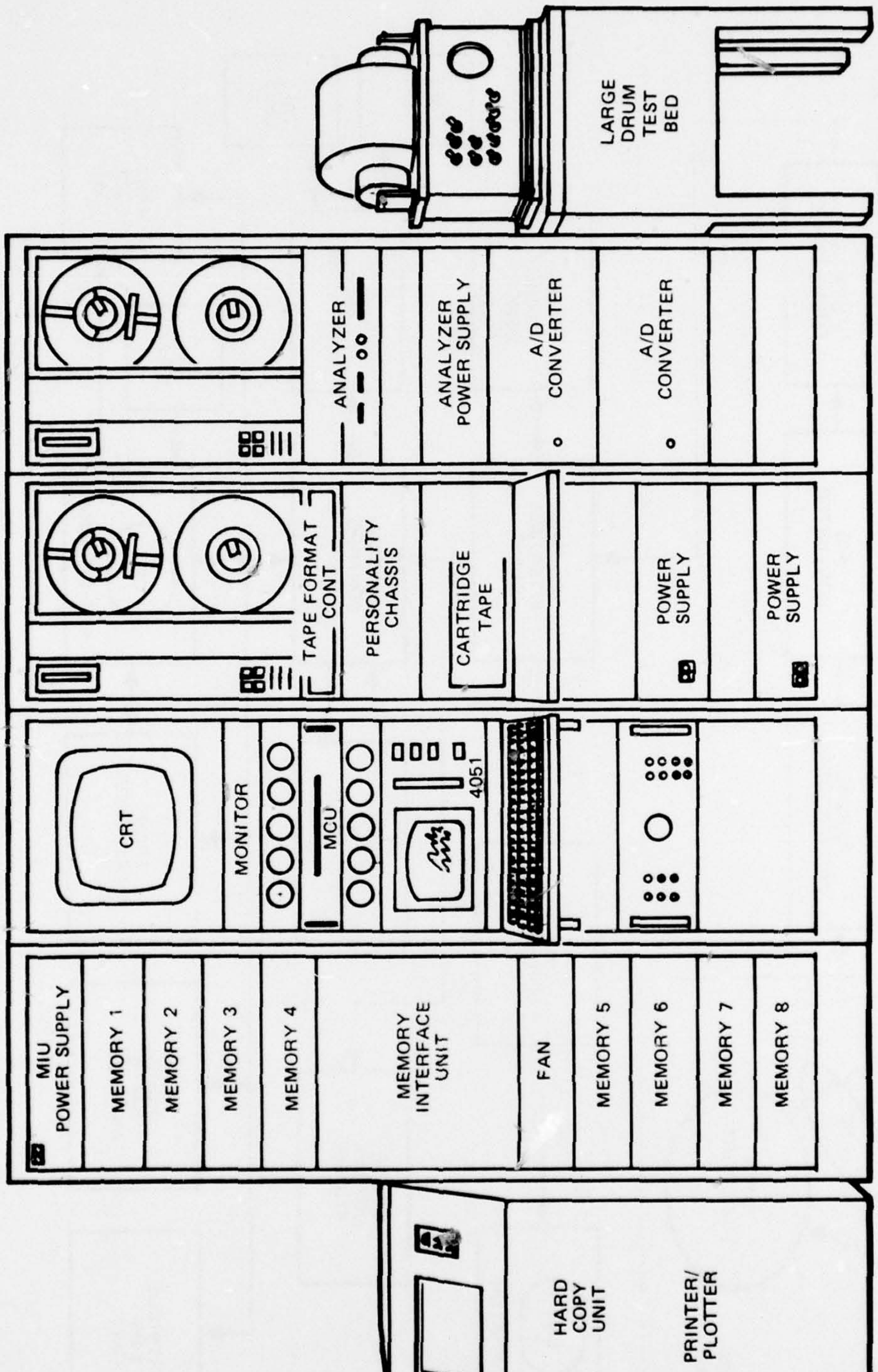


Figure D1. Image capture and analysis system (ICAS) hardware.

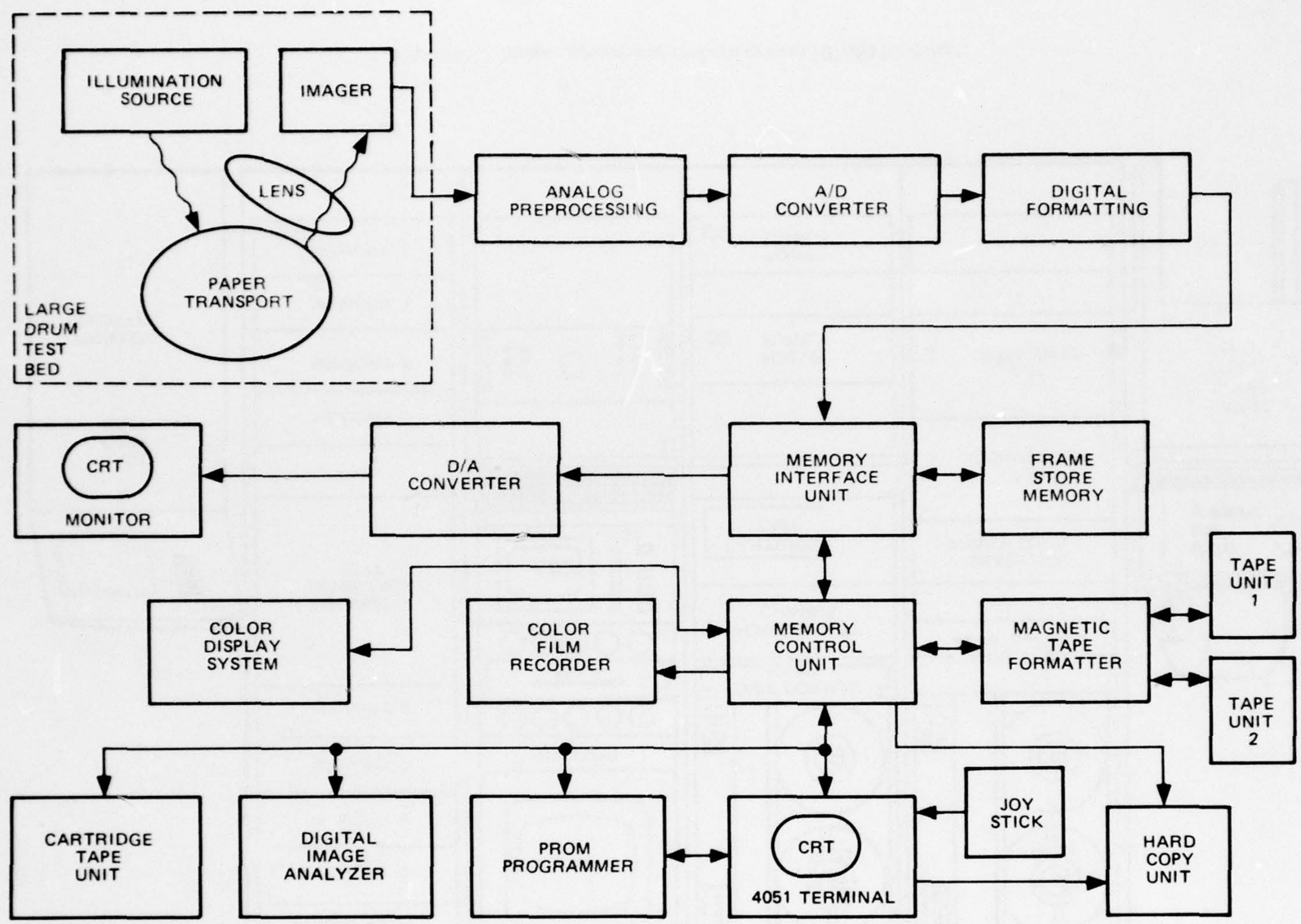


Figure D2. ICAS block diagram.

2. Locate the desired Kennedy nine-track tape containing the appropriate MCU software. (Usually the highest-numbered image tape or a tape labeled "Program Tape.") Load the magnetic tape on tape drive 1, the left-hand unit, following the instructions printed inside the tape drive cover.

3. Press the LOAD button on the tape drive. The tape should run forward to its load point and stop. If, during the loading procedure, the tape is moved past the load point, it will continue to move forward indefinitely. If this occurs, press REWIND and the tape unit will return the tape to its load point and stop. At this point press the ON-LINE button and verify that the Load Point and On-Line lights, located on the tape drive test panel, are on.

4. To load the MCU executive software, press the front-panel control on the MCU labeled LAMP TEST. The tape unit should read forward one record, pause, rewind, and read forward a second time before stopping.

5. To verify the proper software loading, press STEP MACRO to halt machine operation. Verify the program counter by setting the lever switch in the upper right-hand corner of the MCU to 9 and press R_n=. The display should indicate octal 40 or 42 and should indicate 40 or 42 as you alternately press STEP MACRO and R9=. After verification press RUN. At this point the ICAS is initialized and ready to accept system commands from the 4051 terminal.

SCANNER EQUIPMENT POWER UP

The three major components of the scanning equipment which must be powered-up are the *LDTB, the A/D converter, and the personality chassis (PC).*

LARGE DRUM TEST BED

1. Make sure both FAST and SLOW drum switches are in the off position.
2. Turn on the POWER switch.
3. Turn on both the 5V and 15V power supply switches.
4. Turn the intensity control to something greater than 50 percent.
5. Switch the POLARITY switch (done once a day only).
6. Turn on the LIGHT (Filament) switch.
7. After a few seconds push the START button (possibly several times until both lamps are lit).
8. Turn off the LIGHT (Filament) switch.

A/D CONVERTER

1. Turn on the single front-panel power switch.
2. Transmit the gain and level command to the chassis by pressing the two pushbutton switches mounted on the LDTB card, in card slot six.

PERSONALITY CHASSIS

1. Turn on the single front-panel switch of the lower power supply located in the lower portion of rack 3 of the ICAS.

Once these procedures have been completed along with the power-up procedure described earlier, the ICAS is ready for image capture and analysis.

IMAGE CAPTURE AND RECORD

Before any images are captured and stored on magnetic tape, it will be assumed that, at the beginning of each day, a white standard illumination curve will be captured from the LDTB via the white standard. The following procedures explain the capturing of the white standard (along with the generation of correction tables) and of test images.

WHITE STANDARD

To set up the light intensity for scanning the white standard, place the white standard material, which is currently a sheet of 8 X 10 glossy photographic paper, on the drum and secure it with tape. Rotate the drum so a portion of the photographic paper is directly in front of the scanner. Next, set LDTB function control switches 1 and 4 to CONTINUOUS CAPTURE and ENCODER CLOCK DISABLE, respectively. This should provide continuous scan information to the A/D converters. See LDTB Function Control below for an explanation of these control switches.

There are two A/D converters in each chassis. On each A/D converter there is a group of LEDs. There is a row of six LEDs on top which merely reflect the status of each of the six bits output from the converter. The bottom row contains two sets of four LEDs. The four LEDs on the right decode the lowest four brightness levels out of the A/D converter. They are levels 0, 1, 2, and 3, with level 0 being the rightmost LED. The next four LEDs for that channel decode the four brightest states; that is, 60, 61, 62, and 63 (leftmost). 63 is the brightest possible output from the converter. By placing a lens cover over the lens to block out light, the electronics should be set so that level 1 or 2 is very brightly lit; level 0 or 3 may flicker.

With the lens uncovered and the white standard mounted, the illumination intensity control should be adjusted so that the four high-order states are illuminated, with state 63 flickering. That is, state 63 should be output from the converter only occasionally. While this procedure is being followed, it should be noted that the eight LEDs decoding brightness levels on the A/D converter should be flashing on and off, not staying on continuously. A reset command initiated internally resets the LEDs and turns them off after every 16 lines scanned by the imager. If these lights are not flashing or being reset, chances are that the scanner control has not been set properly. If this is the case, the appropriate controls should be rechecked.

After the illumination has been properly set, turn function control switches 1 and 4 off and switch 2 on so that the DRUM SYNC input is disabled. Next, press the MASTER CLEAR button on the LDTB to stop the scanning function. Also, make sure that the slow drum motor is not running. Manually position the portion of the white standard to be captured in front of the scanner. Assuming the software has been loaded into the MCU memory and into the 4051 terminal, press User Definable Key (UDK) 2 to load the image processor functions into the terminal for execution.

To capture the white standard and generate illumination correction tables, enter TAB followed by a RETURN on the terminal. The first response requested is the correction bit precision. Unless otherwise instructed, the response will always be 10. For the source of white sums, enter 2 (captured from white standard). The next question asks the number of lines to be skipped between lines taken for the white standard. This is normally about 25 lines for the current system configuration. The scanner should now be set up for scanning, after which press RETURN on the terminal. Next, press the CAPTURE button on the LDTB, then turn on the slow drum motor. If the capture proceeds properly, the Capture light on the MIU (the center LED) will light momentarily, after which the MCU light (the right LED) will come on. This indicates that the scanning of the white standard has been completed. Allow about 90 seconds for the MCU to complete the generation of the correction tables.

When table generation has been completed, the terminal will respond by displaying IP followed by a prompt, waiting for the next command to be entered. The illumination curve may now be verified by plotting it on the terminal. To do this, type "/" followed by a RETURN to exit from the Image Processing file. Then depress UDK 4 to load the Statistics Output program into the terminal. Once the programs are loaded, select Option 3 – Illumination Curve Plotting routine, and answer the appropriate questions. The terminal will plot the illumination curve on the CRT. After verification, if desired, the white standard information may be written onto magnetic tape. To do this, press UDK 1 for the Monitor Command file. Next, position the magnetic tape to the desired file for writing the white standard. Use the WRI command to write to the desired transport from location 30000_8 to location 33777_8, followed by a File mark. The information should be recorded in the operations book for the particular tape on which that white standard has been written.

TEST IMAGE

To capture a test image, place the image on the drum so that the top of the image is aligned with the fiducial mark on the left end of the drum. Carefully center the image on the drum and secure it with tape, putting as little tape as possible on the image itself. The LDTB function switches should all be set to the off position. The MASTER CLEAR button should be pushed to stop any scanning operation, the slow drum motor should be turned off, and the illumination intensity should be adjusted if desired. Rotate the drum so that the top of the image is just ahead (below) of the scanning station so that a delay of an entire drum revolution is not encountered when the CAPTURE button is pressed. Once the scanner is set up, load the Image Processing file into the terminal and initiate the CAPTURE COMMAND. Answer all questions as to which transport and file number the image is to be stored on and the number of lines to be captured, which is normally 2200 for an 8½-by-11-inch image scanned at 200 pels per inch. Then press RETURN on the terminal to start the capture process, turn on the slow drum motor, and press the CAPTURE button. Do not reverse the order of the last two operations because a transient pulse will be generated causing a false Drum Sync signal to be generated, which will start the capture at the wrong place on the drum.

DISPLAY

The ICAS CRT displays 482 lines by 480 pels. At this time, with two memory modules functioning, display can move left or right a total of 1728 pels. (Presently only X axis

movement exists. With four or eight memory modules functioning, X and Y axis movement will be possible.) This process is accomplished with the joystick at the right of the 4051 terminal.

To initiate a display, press the IMAGE PROCESSING button (UDK 2). Type DIS, press RETURN, and answer all questions. When the scale has been printed on the 4051 CRT, press RETURN, thus displaying the image on the ICAS CRT.

Once the image is displayed, six different bit precisions and six different bit planes may be viewed. This process is accomplished by positioning the two white thumbwheel switches on the front panel of the MIU. The right switch, for bit precision control, displays six levels of precision (1-6) and a grey scale test pattern (7), and enables the left switch (0). The left switch, for bit plane control, displays six bit planes (1-6) and two test patterns – all zeros (0) or all ones (7).

HARD COPY

Presently the ICAS includes a Versatec electrostatic printer/plotter for hard-copy output. Any information displayed on the 4051 terminal can be copied along with bilevel images from either magnetic tape or frame-store memory.

To execute copying from the 4051 terminal, the Versatec unit must be turned on. Next, press the COPY button on the upper right corner of the 4051 terminal. After each printing, press FORM FEED on the Versatec, thus advancing the paper one page.

To execute full-page printing, press the Image Processing button (UDK 2). Type PRI, press RETURN, and answer all questions (presently choose only bit planes 1-6 and use no function table).

STATISTICAL ANALYSIS

There exist two files of statistical programs in the ICAS. These files are Statistics Analysis and Statistics Output. The Analysis file is used for gathering and storing statistical information. The Output file is used for formatting and printing image statistics.

ANALYSIS

1. Serpentine Analysis: Execution of this program requires approximately 1.5 hours for standard image sizes and generates the following statistics:

   a. Pel brightness statistics (PBS)

   b. First difference statistics (FDS)

   c. Run length statistics (RLS)

2. Brightness Analysis: Execution of this program requires approximately 10 minutes for standard image sizes.

   a. PBS

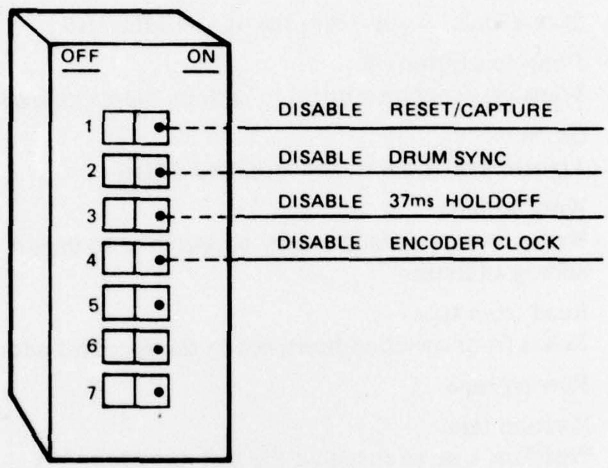
   b. FDS

OUTPUT

1. Serpentine analysis statistics
2. Compression ratios from serpentine analysis
3. Illumination curve plotter
4. PBS-FDS statistics

LDTB FUNCTION CONTROL

LDTB FUNCTIONAL CONTROL



LDTB FUNCTION CONTROL SWITCH

Located at the rear of the card in slot 10 of the LDTB is a seven-pole dual in-line package (DIP) switch. The top four switches are used to control the scanner functions.

The top switch, switch 1, is used to allow continuous scanning. With switch 1 in the on position, the scanner continuously outputs data. In the off position, the scanner does not begin outputting data until the CAPTURE switch is depressed.

The second switch is the DRUM SYNC DISABLE switch. With switch 2 in the off position, data output from the LDTB does not occur until the drum has been turned on and the drum rotates through its initial position, which is marked on the left end, or the encoder end, of the drum. When this mark passes the scan station, a single pulse is generated from the shaft encoder initiating the start of a scan. With this switch in the on position, this pulse output from the encoder is not needed to start a scan. The scan is started immediately after the ICAS CAPTURE button, located below the card cage, is pushed.

The third switch is used to inhibit a timing function when data are captured into memory rather than magnetic tape. Presently all data captured are stored on magnetic tape. Therefore, leave switch 3 in the off position.

Switch 4 is used to inhibit encoder clock pulses from controlling the scanning rate of the LDTB. With switch 4 in the off position, and during image capture, a line of data is output to the A/D converter each time a positional clock pulse is received from the shaft encoder. With switch 4 in the on position, the scanner output is continuous and is not controlled by the shaft encoder clock.

ICAS SYSTEM CONTROL COMMANDS

To utilize ICAS system control commands, first press the appropriate UDK, wait for the prompt symbol, type in the three-letter command mnemonic, press RETURN, and answer all questions.

MONITOR COMMANDS (UDK 1)

RET – Retrieve data
Recovers 48-bit words from the MCU to the 4051

STO – Store data
Stores 48-bit words from the 4051 to the MCU

JSR – Jump to subroutine
Transfers program control to address the specified subroutine

GOT – Go to
Transfers program to any specified address

WRI – Write to tape
Writes on tape from memory to specified transport at specified beginning/ending addresses

REA – Read from tape
Reads from specified transport to the specified address

REW – Rewind tape

POS – Position tape
Positions tape to specified file and record

FIL – File mark on tape
Writes a File mark on the specified tape unit

SBK – Skip block on tape
Skips the next record on specified transport

BBK – Back block on tape
Reverses one record on specified transport

SFK – Skip file on tape
Skips the following file on specified transport

BFF – Back file on tape
Reverses one file on specified transport

MOV – Move contents of memory
Transfers a block of memory from one address to another in the MCU memory

CON – Fill memory with constant
Fills a specified portion of memory with a constant

TEX – Text entry
Stores canned messages in MCU memory

DEN – Set density on tape
Establishes either 800 or 1600 cpi on tape

INS – Inspect and change
Examines or modifies words in MCU memory

SEA – Search memory
Allows selective examination and modification of a portion of memory based on a specified bit pattern

MEN – Monitor command menu
Displays the full set of monitor commands on the 4051 terminal

IMAGE PROCESSING COMMANDS (UDK 2)

DIS – Display image
Displays a 482-line by 480-pel image from either tape or memory. Also, a "split-screen" option is available for any combination of two images

SAV – Save display on tape
Writes a display size image from memory to tape

COP – Copy image from tape to tape
Copies one record at a time with many optional transformations

REW – Rewind tape

TAB – Correction table generation
Generates two correction tables: calibration value table and transformation table

SUM – Image summation
Sums the brightness levels for a specified number of lines

RES – Resolution test

CAP – Capture image
Initiates the image capturing process

CON – Convert status
Allows conversion of different image tape formats into ICAS format

SHI – Shift
Also converts different image tape formats into ICAS format. Used in conjunction with CON

CNS – Constant
Fills a specified portion of memory with a constant

GOT – Go to
Transfers program to specified address

PRI – Print image
Prints entire 8.5-by-11-inch image from tape or memory on the Versatec hard-copy unit in a bilevel format

MEN – Image processing menu
Displays full list of image processing commands on 4051

COMMON ERROR RECOVERY

Many errors may occur in operating the ICAS which will "tie up" the MCU and the 4051 terminal; ie, processing will be halted. Recovery from most common errors is accomplished by the following procedure:

1. Press BREAK key on 4051 terminal twice
2. Press SYSTEM RESET on MCU front panel
3. Position the MCU lever switches to 1000
4. Set register select switch to 9 (upper right corner)
5. Press "Rn="
6. Press SET DATA (sets 1000 into register 9)
7. Press RUN
8. Press appropriate UDK on 4051 terminal to restart program
9. If the error still exists, contact the programmer

POWER DOWN

The following procedure must be followed to correctly turn off the ICAS system.

1. Rewind magnetic tapes on Kennedy transports 1 and 2. Rewind the Terminal Executive tape cartridge in the 4051 terminal.

2. Press PAGE, on the 4051 terminal, approximately eight times to clear the CRT. Eject the Terminal Executive tape cartridge from the 4051 terminal.

3. The following equipments must be turned off:

   a. Tektronix 4051 terminal

   b. LDTB

   c. A/D converter

   d. Power supply to personality chassis

4. Turn off the three lower 110-volt circuit breakers located on the east wall of room 3306.